Evaluating human-carnivore coexistence using a multi-stakeholder socio-ecological approach

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Abstract

Understanding and managing interactions between humans and carnivores is a major conservation challenge. For strategies aimed at facilitating human-carnivore coexistence (HCC) to be evaluated against their desired goals, stakeholders' perspectives on coexistence and strategy effectiveness must be understood. However, such an approach is rarely conducted, creating missed opportunities for improving promising strategies. This study explored HCC using a multi-stakeholder socio-ecological approach with a particular focus on stakeholder perceptions and measures of success pertaining to interventions designed to increase HCC. Participants in the study included commercial livestock farmers, conservationists and protected area managers involved in HCC scenarios in the Limpopo Province, South Africa. Using a grounded theory approach, perceptions of successful intervention strategies (aimed at increasing HCC) were explored. Factors that contributed to perceptions of strategy effectiveness included livestock type, herd size and source of income. Moreover, coexistence ranged from being a concept considered achievable by the majority of stakeholders, to one which might only be feasible under certain conditions. Evaluating interview and camera trap data concurrently provided novel insights into how information from different sources can be used to justify different perspectives. This was particularly evident in regard to perceived carnivore population size. The use of Q-method identified areas of stakeholder consensus, for example, recognition that complete cessation of depredation is an unrealistic ideal, but also exposed areas of potential inter-stakeholder conflict about priorities and expectations for intervention success. The importance of understanding and exploring the perceptions of all stakeholders when implementing intervention strategies was highlighted in order to properly define and evaluate the achievement of HCC goals. Stakeholder-derived recommendations for future interventions focused on the need for transparency, shared success criteria, and on-going communication. Furthermore, this research revealed the importance of defining context-specific goals and developing trust-based relationships such that success in the context of HCC scenarios can be evaluated according to stakeholder experience and perceptions.

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Publications included in this thesis

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List of Abbreviations

AWCRC: Alldays Wildlife and Communities Research Centre

COT: Cheetah Outreach Trust

FAO: Food and Agriculture Organization

GBP: Great British Pound

GDP: Gross Domestic Product

GDPR: General Data Protection Regulation

HCC: Human-Carnivore Coexistence

HCI: Human-Carnivore Interaction

HWI: Human-Wildlife Interactions

LEDET: Limpopo Economic Development, Environment and Tourism Department

LEK: Local Ecological Knowledge

LGD: Livestock Guardian Dog

NGO: Non-Governmental Organisation

PA: Protected Area

PAA: Protected Area Authority

ZA: South African Rand

Chapter 1: Introduction

1.1 Why conserve carnivores?

In the last two centuries, many of the world's carnivores have experienced substantial population reductions and range contractions (Ripple *et al.,* 2014). The global contraction of carnivore species is caused by a number of ecological, biological and anthropogenic factors (Kissui, 2008). Examples of these factors include increasing human population density, habitat loss and fragmentation, reduced prey and elevated rates of conflict (Schuette, Creel and Christianson, 2013). In recent decades, human populations and activities have expanded greatly with the global population expected to grow from 7.7 billion in 2019 to 8.5 billion in 2030 (UNPD, 2019). This means that every year humans encroach into uninhabited lands and protected areas (Chapron and López-Bao, 2016). As a result, more land is claimed for agricultural purposes, transforming natural ecosystems (Nadel, O'Riain and Scotcher, 2012). In addition to agricultural expansion, environmental decline occurs through anthropogenic activities such as logging and poaching. These activities threaten tropical forests and wildlife in particular (Krief *et al.,* 2014). Environmental degradation forces wildlife to forage outside of forested or protected areas and approach human inhabited environments (Carter and Linnell, 2016; Torres, Oliveira and Alves, 2018). This, along with changing land use increases the likelihood of human-carnivore encounters with potentially detrimental outcomes for one or both sides, which in turn threatens the survival of some carnivore species (McKay *et al.,* 2018).

The order Carnivora includes around 245 terrestrial species (Ripple *et al.,* 2014), many of which are apex predators that drive the structure and function of biological communities in diverse ecosystems (Holland, Larson and Powell, 2018). Carnivores help to regulate ecosystems across the world through direct and indirect pathways. Subsequently, their removal can have significant consequences on these ecosystems (Treves and Karanth, 2003; Torres, Oliveira and Alves, 2018), for example, causing a trophic cascade known as meso-predator release (Green *et al.* 2018). Consequently, the persecution of large carnivores has benefited some meso-carnivores through a reduction in competition (Lennox *et al.,* 2018). However, the presence of carnivores also limits large herbivore populations (Ripple *et al.,* 2014). Without such natural regulation, herbivore populations can expand and create forage competition with livestock. Furthermore, the presence of carnivores provides several direct and indirect benefits to human health and well-being, for example the presence of jackals is linked to economic benefits through pest control in agricultural areas (Srivathsa *et al.,* 2019).

Whilst there are many factors associated with the decline of carnivore species, persecution by humans is considered one of the leading causes (Ripple *et al.,* 2014; Woodroffe, Thirgood and Rabinowitz, 2018). Carnivores are particularly affected by increasing human population growth due to their large home ranges, slow life histories and dietary requirements that often draw them to human dominated landscapes (Treves and Karanth, 2003; Inskip and Zimmermann, 2009; Gebresenbet *et al.,* 2018; Green *et al.,* 2018). Carnivores are among the first species to disappear from transformed landscapes. For example, in African landscapes, lions (*Panthera leo*) are particularly vulnerable to persecution from humans and are often the first large carnivore species to be eradicated from areas (Oriol-Cotterill *et al.,* 2015). Other carnivores such as leopard (*Panthera pardus*) and spotted hyena (*Crocuta crocuta*) are better able to persist in areas of human persecution due to their wide habitat preferences and diverse diets (Davis *et al.,* 2021). Carnivores living in areas of high human density face a landscape of fear and as a response they may adjust their spatial movements and activity patterns to avoid potentially fatal interactions (Goswami *et al.,* 2014; Loveridge, Valeix, *et al.,* 2017). Despite this, some carnivore species may try to trade off activities against human-caused mortality (Oriol-Cotterill *et al.,* 2015). A human modified landscape may contain valuable resources such as food and water, which offsets such risks (Oriol-Cotterill *et al.,* 2015). Behavioural sensitivity to humans is not uniform; carnivore species differ in their response to human activities with some species showing preference for human occupied areas such as farms to avoid inter-specific competition and gain increased access to water via livestock boreholes (van der Weyde, Mbisana and Klein, 2018). Studies exploring spatial and temporal partitioning have shown that carnivores, such as lions, can become more nocturnal in human-occupied areas to allow for use of areas at times when risk of detection by people is lowest (Oriol-Cotterill *et al.,* 2015). Similarly, in South Africa the caracal (*Caracal caracal*) shows increased nocturnal movements on agricultural lands suggesting avoidance of periods with most human activity (Ramesh, Kalle and Downs, 2017). It is thought that the wide and varied diet of the caracal has allowed them to readily adapt to areas of increased human activity which may have high prey availability (e.g., rodents in crop fields) (Ramesh, Kalle and Downs, 2017; Drouilly *et al.,* 2018). However, behavioural adjustments and avoidance patterns in relation to human presence are species-specific and best seen at local scales, and in direct response to locations of human activities (Snyman *et al.,* 2018).

1.2 Human-wildlife interaction terminology

In academia and the scientific literature, much debate on carnivore conservation has centered on the terminology used to describe interactions between humans and carnivores. Discussion has largely focused on the use of the term 'conflict' to describe negative interactions. Use of the term has been criticised for a number of reasons including positioning interactions as predominantly negative, taking a human-centric approach and neglecting to consider the role of conflict between stakeholder groups (Davidar, 2018; Margulies and Karanth, 2018; König *et al.,* 2020). Davidar (2018) even went as far as to suggest that the terminology applied to the field of human-wildlife interactions could make a difference as to whether a species survives or disappears forever.

The term human-wildlife conflict was bought to the global stage in 2004 at the International Union for Conservation of Nature's (IUCN) World's Park Congress, where it was defined as occurring when "the needs and behaviour of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact wildlife needs. These conflicts may result when wildlife damage crops, injure or kill domestic animals, threaten or kill people" (Madden, 2004, p.248). This definition has become the most widely used in the conservation literature (Davidar, 2018) and human-wildlife conflict has since emerged as a central vocabulary for conservation studies which primarily look at competition over resource use (Peterson *et al.,* 2010). The study of human-wildlife interactions has been increasing exponentially since 1995 (Nyhus, 2016). Despite emerging relatively recently as a conservation buzz term, conflict between wildlife and humans has been documented since the early 1990s (Sukumar, 1991; Newmark *et al.,* 1993). However, these studies used terms describing human outcomes of the interactions (e.g., 'livestock depredation') rather than conflict to describe human-wildlife interactions (Jhala, 1993; Oli, Taylor and Rogers, 1994). Thus, it can be argued that these early studies focused almost exclusively on the consequences to humans, rather than impact on wildlife or characterising the interactions between humans and wildlife.

Use of the term human-wildlife conflict has also been criticised for suggesting that wildlife are conscious human antagonists thereby framing wildlife through an anthropomorphic lens in which wildlife can act purposefully against humans (Redpath *et al.,* 2013; Davidar, 2018). This implies that wildlife not only have their own goals and interests, but an awareness of human goals and will deliberately act to prevent them from being achieved (Woodroffe and Frank, 2005; Peterson *et al.,* 2010). In this sense, the term human-wildlife conflict places wildlife on an equal footing with humans in the role of combatants, despite the fact that they cannot represent themselves in the political sphere (Raik, Wilson and Decker, 2008; Peterson *et al.,* 2010; Davidar, 2018). Furthermore, the term human-wildlife conflict could be seen to dichotomise humans and nature by framing wildlife as something that threatens humans and therefore places humans outside the category of wildlife i.e., not natural (Peterson *et al.,* 2010).

Despite increase in use of the term human-wildlife conflict, it is not just about the inherent assumption that it causes problems between humans and animals but also between groups of people over wildlife (Madden, 2004). Many human-wildlife conflicts are not only complicated but defined by underlying tensions between people with different views on the conservation of wildlife, resource and land use (Nyhus, 2016; Gebresenbet *et al.,* 2018). Human-human conflicts over wildlife present a serious and growing threat to the survival of some species (Zimmermann, McQuinn and Macdonald, 2020). This has come to light more recently in the literature, as evidenced by the increase in publications acknowledging the human aspects of human-wildlife conflicts (Frank, Glikman and Marchini, 2019).

Conflicts often arise when groups of people disagree about wildlife and conservation priorities (Holland, Larson and Powell, 2018). Human-human conflict tends to emerge when deciding how best to address potential wildlife threats to human property, health or safety (Peterson *et al.,* 2010). Intolerance for other groups of people therefore often plays out as intolerance for non-human species (Slagle and Bruskotter, 2019), for example, conducting retaliatory killing to spite conservation policies as documented among Maasai pastoralists in Amboseli, Kenya (Fernández-Llamazares *et al.,* 2020) and farmers in the Northern Cape, South Africa (Terblanche, 2020). Subsequently, visible human-wildlife conflicts may be expressive of socio-economic and political differences between groups of people at local, national and international levels (Davidar, 2018). Therefore, the origins of negative interactions tend to stem from beyond the superficial impacts e.g., livestock loss, and are often linked to deeper issues such as power relations, politics, social and cultural history (Redpath *et al.,* 2013). Furthermore, the drivers of many conflicts are rooted in larger societal issues such as poverty and inequality (Baynham-Herd *et al.,* 2018). Addressing human-wildlife conflicts could therefore be divided into those that deal with interactions between humans and wildlife species and those that deal with human-human conflicts which arise between those seeking to conserve wildlife and those with other uses of the land (Redpath *et al.,* 2013). To produce the desired conservation outcomes, it is essential to distinguish which conflict is being dealt with and determine the scale (e.g., local, national or regional). Subsequently, the labelling of conflicts as human-wildlife conflict allows for human-human conflict to be masked (Peterson *et al.,* 2010). Consequently, concern has been raised that the term human-wildlife could obscure what may actually be the root of many problems expressed as conflict (Peterson *et al.,* 2010; Margulies and Karanth, 2018). Using the term human-wildlife conflict has enabled non-human animals to become scapegoats in conflicts which are actually between groups of people with different ideologies (Margulies and Karanth, 2018). By using the term human-wildlife conflict, human conflicts are therefore projected onto wildlife (Knight, 2013) and assumes a negative relationship between humans and wildlife.

Debate surrounding the term human-wildlife conflict is not just limited to ignoring the role of human-human conflict but is part of a much wider discussion in the conservation literature. The term is also accused of positioning interactions between wildlife and humans as inherently negative when interactions can be positive or neutral (Margulies and Karanth, 2018). Humans and wildlife have always lived alongside each other and interacted to varying degrees. In many situations, humans and wildlife experience interactions and overlap without the need to label interactions as conflicts (Frank, Glikman and Marchini, 2019). However, rather than occupying extreme ends of a liner scale, it should be recognised that coexistence does not necessarily occur in the absence of conflict and vice versa (Pooley, Bhatia and Vasava, 2021). Additionally, the relationship between humans and wildlife is not static and constantly evolves. It is also important to note that within even the same social community, wildlife can have both positive and negative societal benefits and value to people. For example, farmers may have a different opinion of wildlife compared with those working in the wildlife tourism industry. Therefore, the term human-wildlife conflict is not representative of the complexity of interactions between humans and wildlife, and its use limits the scope for recognising positive interactions (Messmer, 2000).

Another perspective argues that the term human-wildlife conflict developed from a conservation orientated perspective which puts the needs of wildlife first and neglects to address the needs of the involved people and underlying causes of the contention (Glikman, Frank and Marchini, 2019). The conservation orientated approach to studying negative human-wildlife interactions has traditionally focused on reducing the tangible impacts caused by wildlife through bio-physical and economic solutions (Madden, 2008; Pooley *et al.,* 2017). Therefore, the term human-wildlife conflict could be considered a constraint on conservation practitioners as it directs focus on reducing negative interactions rather than increasing positive relationships (Frank, 2016). Examining positive interactions and the factors (i.e., values, culture and location of residence) that foster positive perceptions and coexistence with wildlife may aid in better understanding how conservation goals can be achieved (Frank, Glikman and Marchini, 2019; Pooley, Bhatia and Vasava, 2021). Framing human-wildlife conflict from a conservation perspective has largely led to the invention and implementation of interventions designed to prevent interactions from occurring, which may work in particular circumstances, but do not actually address underlying causes and issues of conflict (Redpath, Bhatia and Young, 2015). As part of the shift away from using the term human-wildlife conflict, there is a trend to integrate conflict-focused approaches with community development initiatives (Frank, 2016). This demonstrates a need to move towards a more holistic discourse which recognises that not all interactions between humans and wildlife are negative and not all solutions are solved (or solvable) by removing/reducing negative interactions.

Interactions between humans and wildlife clearly encompass much more than competition over land use and resources which provided the original basis for use of the term human-wildlife conflict. The wide range of perspectives on use of the term human-wildlife conflict, makes it difficult to define the issue in a way that it is inclusive, comprehensive, precise, succinct, and user-friendly (IUCN HWC Task Force, 2020). The term is now associated with many negative connotations and alternatives have emerged in the literature. There is a growing movement towards changing the labelling of human-wildlife conflict to human-wildlife coexistence (discussed in 1.6) or human-wildlife interactions (discussed in 1.3) (Woodroffe and Frank, 2005; Peterson *et al.,* 2010; Frank, 2016; Nyhus, 2016). The terms human-human conflicts and conservation conflicts have also been used (Hill, 2015). The term ‘human-wildlife interactions’ (HWI) arguably better communicates the entire spectrum of relevant relationships involved in moving from conflict to coexistence scenarios (Frank, Glikman and Marchini, 2019), although could still be seen to reinforce a distinction between humans and wildlife. The changing use of terminology reflects that it is now widely acknowledged that HWIs are generally more complex than just conflicts over resources. This shift also recognises that humans are not only part of the problem but the solution as well (Frank, Glikman and Marchini, 2019).

1.3 Human-wildlife interactions

The term human-wildlife interaction(s) (HWI) is used to cover a range of interactions between people and wildlife. Interactions between humans and wildlife exist on a broad spectrum that ranges from negative to positive (Glikman, Frank and Marchini, 2019). Interactions between people and wildlife can be simultaneously positive, neutral and negative (Soulsbury and White, 2015), they may be rare, frequent, brief or long (Soulsbury and White, 2015; Nyhus, 2016). How wildlife is viewed by a society can determine the outcome of human-wildlife interactions and, depending on the context, will translate into a positive, neutral or negative situation (Frank, Glikman and Marchini, 2019). From a human perspective, positive interactions include, for example, tourism, photographic safaris and spending money to engage with or help protect wildlife (Soulsbury and White, 2019). Such experiences provide people with encounters with wildlife from which pleasure is derived (Curtin, 2009). These experiences can also benefit wildlife by promoting a stronger connection to nature and therefore a greater likelihood of conserving the natural world (Curtin, 2009). Within communities, interactions between humans and wildlife can be interpreted differently depending on people’s occupation and financial status. For example, seeing a particular species may be positive for safari guides but negative for livestock farmers. Rural communities are often more exposed to the costs of living alongside wildlife and may perceive interactions as negative. In contrast, urban residents have fewer direct negative experiences and are generally more positive about wildlife (Mech, 2017).

Negative HWIs with terrestrial mammalian carnivores tend to involve felids (Felidae), canids (Canidae), bears (Ursidae) and hyaenas (Hyaenidae). Within these groups certain species are more prone to negative HWIs than others and is largely connected to body size and proximity to human-dominated landscapes (Zimmermann *et al.,* 2010). Negative HWIs are described as occurring when “the presence or behaviour of wildlife poses actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/ or wildlife” (IUCN HWC Task Force, 2020, p.2). Where carnivores and humans cohabit, competition for resources can result in depredation of domestic livestock, human injury or death and the potential transmission of zoonotic disease from wildlife to humans and/or livestock (Gebresenbet *et al.,* 2018;

Torres, Oliveira and Alves, 2018). Attacks on humans by carnivores are usually rare compared with livestock loss but can be lethal and elicit strong reactions from humans (Dunham *et al.,* 2010; Nyhus, 2016). Furthermore, where attacks on humans do occur, they can be heavily publicised (Packer *et al.,* 2005). How such attacks are framed by the media can shape public attitudes towards species (Rust, 2015) and fear of attack can provide motivation to kill carnivores (Inskip *et al.,* 2014). Livestock can be easy targets for carnivores as they are often abundant, less vigilant than wild prey, and can be easily accessible, especially if herded into enclosures or visible on grazing landscapes (Ogada *et al.,* 2003; Woodroffe *et al.,* 2007; Bickley *et al.,* 2019; Gray *et al.,* 2020). Declines in wild prey populations through forage competition with livestock can also cause changes to the predatory patterns of carnivores (Soofi *et al.,* 2019). Livestock loss from predation is usually low but varies locally and can cause significant economic losses at an individual level (Kissui, 2008; Weise *et al.,* 2018). In the Serengeti, pastoralists reported that losses by depredation amounted to approximatively 19% of their annual cash income (Holmern, Nyahongo and Røskaft, 2006). In South Africa, livestock predation has been estimated to cost in excess of ZAR1 billion per year (GBP 49.8 million) (Kerley *et al.,* 2017). Therefore, the presence of carnivores on agricultural lands can lead to loss of stock, expenditure on intervention measures to prevent losses, or costs involved through a combination of losses and intervention use (Kerley *et al.,* 2017).

Negative HWIs occur globally and can affect people in both the global south and north, and is independent of national income classification (Seoraj-Pillai and Pillay, 2016). It is thought that millions of people across the world are affected by negative interactions with wildlife (Barua, Bhagwat and Jadhav, 2013). In South Africa, a number of carnivore species are reported to interact negatively with people, including: black-backed jackal (*Canis mesomelas*), caracal, lion, leopard, cheetah (*Acinonyx jubatus*), Cape fox (*Vulpes chama*), African wild dog (*Lycaon pictus*), spotted hyena, brown hyena (*Hyaena brunnea*), serval (*Leptailurus serval*), crocodile (*Crocodylus niloticus*), feral domestic dogs (*Canis lupus familiaris*), as well as various corvids and raptors (Kerley *et al.,* 2017). HWIs are complex and each specific scenario is unique whereby the scale and occurrence of HWIs are shaped by a vast array of factors which can be biological, geographic, political, social, financial, cultural and historical (Madden, 2004). The factors influencing the frequency and severity of HWIs can include habitat availability and degradation, proximity to protected areas, availability of natural prey, livestock husbandry and management practices used, human behaviour and activity patterns, predator density, socio-economic determinants such as religion and education and spatial determinants (proximity to suitable cover/ trees/ water) (Inskip and Zimmermann, 2009; Lesilau *et al.,* 2018). Many risk factors are environmentally specific and whilst negative HWIs are encountered by diverse communities, those living near to protected areas may experience greater impacts from living in close proximity to wildlife

(Dickman, 2008; Gandiwa *et al.,* 2013). Experience with carnivores is therefore very localised (Frank, Glikman and Marchini, 2019). As each HWI scenario is unique, every place and community has developed their own unique relationship with wildlife (Pooley *et al.,* 2017), although some cross-cultural similarities can be seen (Madden, 2004).

Experiencing negative HWIs can have significant consequences for human livelihoods, health, safety and well-being (Nyhus, 2016; Baynham-Herd *et al.,* 2018). Negative interactions can undermine household food security, particularly in low-income countries (Seoraj-Pillai and Pillay, 2016). Moreover, losses that may seem insignificant at a national or global level can severely affect individual families, especially in the poorest parts of the world (Barua, Bhagwat and Jadhav, 2013). Therefore, the long-term consequences of negative HWIs can be felt long after the actual event. The hidden impacts of HWIs include lost opportunities and transactions as well as the impacts on mental and physical wellbeing (Barua, Bhagwat and Jadhav, 2013). The effects of hidden impacts are often determined by poverty, resource access, ethical and political marginalisation (Barua, Bhagwat and Jadhav, 2013). Subsequently an individual's or household's ability to recover from negative HWIs is shaped by non-HWI factors and depends on the ability to access both material and social resources (Khumalo and Yung, 2015). As a result, the impacts of negative HWIs can be hard to measure and can be further magnified by what reactions to wildlife are considered acceptable by those governing decisions over wildlife management (Frank, Glikman and Marchini, 2019). Understanding the hidden impacts of HWIs is vital for conservation and human well-being, however, it is an area that needs more work (Dorresteijn *et al.,* 2016). To date, very little attention has been paid to the experiences and effects on people of life changing encounters with wildlife such as attacks or significant losses of livestock (Pooley, Bhatia and Vasava, 2021). Many studies do not fully consider the psychological consequences for those living alongside wildlife and how they may be affected by negative HWIs (Frank, Glikman and Marchini, 2019). Such considerations may be ignored since human well-being is typically harder to study and measure than the economic consequences of interactions.

1.4 Managing negative interactions

Managing interactions between humans and carnivores is a major conservation challenge across the world (Peterson *et al.,* 2010; Chapron *et al.,* 2014; Bautista *et al.,* 2019). Whilst the conservation of many carnivore species is regarded as a global priority, it is challenging because of their large ranges, low densities and negative interactions with people (Bauer, de Longh and Sogbohossou, 2010). Successful conservation of carnivores therefore depends on both the socio-political and biological landscape (Treves and Karanth, 2003). Effective management of negative human-carnivore interactions (HCIs) can be highly complex as solutions must reconcile human needs with carnivore needs to benefit both conservation and human well-being (Treves and Karanth, 2003; Inskip and Zimmermann, 2009; Miller, 2015). Conservation has arguably become reliant on the commodification of a small number of flagship species e.g., lion and tigers, that appear in advertising and promotion of ecotourism trips (Lorimer *et al.,* 2015). However, such imagery rarely considers the experiences of the people who live alongside such species and may experience negative interactions. Whilst outside of Africa the imagery of lions can be used effectively to motivate support for conservation action, this may not work in regions where free-ranging lions actually occur. Symbolic drivers for conservation are consequently tied to cultural beliefs and perceptions of wildlife (Pooley *et al.,* 2017). Furthermore, deeply rooted cultural hostility towards large carnivores can add further challenges to their conservation (Chapron *et al.,* 2014; Lute *et al.,* 2018). For example, a study on subsistence farmers in Zimbabwe found that lions were viewed negatively with perceptions shaped by location as well as ethnic group (Sibanda *et al.,* 2020). In contrast, a study from Ethiopia showed how cultural beliefs and respect for lions can increase people's tolerance for losses caused by carnivores (Gebresenbet *et al.,* 2018). Understanding and incorporating cultural beliefs into conservation initiatives is therefore important to gain support for conservation (Sibanda *et al.,* 2020), and has been done successfully (e.g., Hazzah et al. 2014).

Many debates surrounding the conservation of carnivores centre on whether humans and carnivores can or should share space, and how this should be managed (Green *et al.,* 2005; Fischer *et al.,* 2008). Opposing viewpoints on this can result in contrasting conservation policies. Protected areas (PAs) preserve land specifically for wildlife and carnivores are increasingly restricted to PAs (Schuette, Creel and Christianson, 2013). However, whilst PAs are an important refuge for many carnivores, they are often too small for large, wide-ranging carnivore species (Lagendijk and Gusset, 2008). The use of PA fences to enclose populations means that carnivore species can become genetically isolated, as documented in African lions (Packer *et al.,* 2013). This necessitates the use of routine genetic and demographic management via translocations of breeding-aged individuals to avoid inbreeding and disease resistance (Trinkel *et al.,* 2008; Johnson *et al.,* 2010). Nevertheless, carnivores cannot always be contained by PA boundaries which leads them to range into adjacent areas where they may interact negatively with humans and supplement their diet with livestock (Kissui, 2008). In Africa, many carnivores such as leopards, lion, cheetah and black backed jackal live outside of PAs which adds to the challenge of their conservation (Lindsey *et al.,* 2013, 2018; Durant *et al.,* 2017). Furthermore, PAs are becoming increasingly disconnected, so carnivores have to traverse unprotected ground to move between them (Madden, 2004; Goswami *et al.,* 2014). Whilst PAs often serve as the last refuges for wildlife- and can increase positive or neutral HWIs through wildlife viewing, the proximity of PAs to private lands can increase the probability of negative HWIs which may undermine conservation efforts

(Amit and Jacobson, 2017). Therefore, increased human population growth at their boundaries is a cause for concern (Wittemyer, 2008), particularly as it is well documented that people living in areas adjacent to PAs are most likely to experience negative HCIs (Anthony, Scott and Antypas, 2010). As human populations at the boundaries of PAs increase, anthropogenic threats to carnivores intensify (Green *et al.,* 2018) and can cause edge effects (see Balme, Slotow and Hunter, 2010). Arguably there is a paradox surrounding the use and management of PAs whereby successful wildlife conservation may lead to increased conflicts with neighbouring communities, particularly from damage causing animals (Anthony, 2007). Additionally in many African countries PAs are under-funded which limits the ability of wildlife authorities to maintain PAs and deal with human pressures (Lindsey *et al.,* 2017). Subsequently, it is argued that whilst PAs are vital for carnivore conservation in order to maintain populations, mixed-use landscapes will be crucial (Lute *et al.,* 2018). Carnivores therefore need to be able to persist in human-dominated environments (Mkonyi *et al.,* 2017). Consequently, private lands, especially farmland, play an important role in biodiversity conservation (Amit and Jacobson, 2017). For example, 77% of current cheetah range occurs outside of PAs (Durant *et al.,* 2017). If farmland is shared with carnivores, a minimum level of predation is still to be expected even with management practices and intervention strategies in place (Crespin and Simonetti, 2019). Understanding these levels of predation and tolerance of loss will be vital to achieving conservation goals.

1.5 Solving and studying conservation challenges

Conservation biology is rooted in quantitative science and conservation actions were traditionally guided solely or predominantly by the natural sciences (Bennett *et al.,* 2017). As a result, researchers can be biased towards focusing on the assessment of nature (Madden and McQuinn, 2014). Whilst ecological data on species population size, distribution, life history, behaviour and ecology are necessary to determine species status, today the majority of threats to the survival of wildlife are anthropogenic (Setchell *et al.,* 2017). Subsequently, conservation challenges are as much about people as they are about wildlife, meaning that the use of ecological knowledge alone cannot solve conservation issues (Fox *et al.,* 2006; Bekoff and Bexell, 2010; Bennett *et al.,* 2016). Many conservation goals require changes in human behaviour, and it is therefore necessary to understand the social factors that shape human interactions with the environment (Fox *et al.,* 2006). Social factors can be more important in driving contention between humans and wildlife than actual wildlife damage incurred, and how people deal with HWIs is heavily influenced by their social values, culture, history and ideology (Dickman, 2010). The success of approaches aiming to understand and manage HWIs is dependent on the extent to which they address these underlying social factors (Dickman, 2010). Subsequently, conservation is now recognised as an interdisciplinary field which accepts the importance of humans in sustaining biodiversity (Sutherland *et al.,* 2018). Whilst in recent years there has been a movement to mainstream the social sciences within conservation practices and policies (Bennett *et al.,* 2017), this awareness does not always translate into practice (Holmes *et al.,* 2021). For example, a survey of >9000 conservationists found only 3% of respondents had training in the social sciences, compared with 60% with training in natural sciences (Sandbrook *et al.,* 2019).

Studies using multidisciplinary approaches to assess HWI scenarios have primarily focused on exploring human attitudes, tolerance and behaviour towards wildlife. Social science surveys are an essential tool used to help understand the drivers and impacts of attitude, tolerance and behaviour; surveys can take on many forms including market surveys, questionnaires and interviews (Nuno and St John, 2015). In HWI studies where a mixed method approach is used, the primary methods used are interviews and questionnaires; such methods are typically used to help gain an understanding of the roots of discord and people's perceptions of wildlife damage (e.g., Bauer, de Iongh and Sogbohossou, 2010; Bickley *et al.,* 2019; Weise *et al.,* 2019). Interviews were often used in conjunction with other social science research methods, e.g., questionnaires, workshops, participatory mapping, Delphi technique and ethnographic models (Young *et al.,* 2018). However, Goldman, De Pinho and Perry (2010) argue that many of these kinds of studies are framed in Western analytical categories and subsequently may overlook ways in which local people think about and relate to wildlife. Moreover, it has been suggested that research on people's attitudes and behaviours has generally sought large representative samples from standardised questionnaires which allows for statistical analysis and broad generalisability (Drury, Homewood and Randall, 2011). Placing such emphasis on quantification may compromise on data quality and validity. Studies aiming to quantify human behaviour have, to date, primarily relied on behavioural assessment through surveys of behavioural intentions or self-reported activities. Whilst these methods facilitate large scale data collection, they may not accurately reflect human behaviours (Lischka *et al.,* 2018). A large mismatch has been noted between assumed, reported and actual behaviour (Dickman, 2010). Discrepancy has also been noted between attitude, intention and behaviour (St. John, Edwards-Jones and Jones, 2010), and these differences should be taken into consideration. Furthermore, many conservation studies that use interdisciplinary, qualitative methods do so with poor justification and inadequate reporting (Sutherland *et al.,* 2018; Pooley, Bhatia and Vasava, 2021; Whitehouse-Tedd, Abell and Dunn, 2021).

One of the key reasons why interdisciplinary methods are so essential in conservation is the fact that local perceptions of wildlife can differ from those of conservationists. Interdisciplinary qualitative approaches help to explore and understand local knowledge and may reveal differences in perspectives among stakeholder groups (Sutherland *et al.,* 2018). Disputes between different groups of people over wildlife management can be difficult to resolve, particularly where people hold different values and worldviews (St John *et al.,* 2018). This is particularly relevant where bonds between people and their place of residence spark resistance to conservation projects (Muhar *et al.,* 2018). For example, in places where PAs have been implemented, locals can experience displacement, disempowerment and/or wildlife damage and as a result can hold resentment towards wildlife-focused agencies (Redpath *et al.,* 2017).

In order to reduce negative HWIs and implement appropriate conservation strategies, common ground among stakeholders must be identified. Multidisciplinary qualitative approaches can reveal differences in perspectives among stakeholder groups (Sutherland *et al.,* 2018). The inclusion of locals in conservation initiatives in a meaningful manner is a complex undertaking (Waters, Bell and Setchell, 2018). However, case studies have shown that conservation failure results when interventions make little attempt at local engagement (e.g., Webber, Hill and Reynolds, 2007). In contrast, involving local communities as key stakeholders in conservation initiatives has proved highly effective (for examples see the work of Dickman (2010) and Hazzah (2006)). Despite these successes, Gray *et al.* (2019) noted that stakeholder engagement in studies of HCIs in East Africa was mostly in the form of responding to surveys and questionnaires rather than direct involvement in the research process. To date, most research on the consequences of HWIs focuses on the costs and benefits for local people (Gebresenbet *et al.,* 2018). This may reflect the interests of conservation researchers for whom solving negative HWIs appears to be largely about reducing economic impact and therefore measure HWIs in these terms. If wildlife management is over simplified and focused only on ecological or economic perspectives, management strategies may fail to take into consideration the diverse needs of different stakeholders and negative HWIs may continue (Amit and Jacobson, 2017; St John *et al.,* 2018).

1.6 What is meant by human-carnivore coexistence?

There is an established trend of setting human–carnivore coexistence as the end goal of conservation efforts, such as the implementation of intervention strategies (Chapron *et al.,* 2014; Elliot, Vallance and Molles, 2016; Fynn *et al.,* 2016; Crespin and Simonetti, 2019). If achieving coexistence is the goal of intervention use, it is necessary to understand what is meant by the term coexistence. Whilst the term coexistence is frequently used in HWI studies (König *et al.,* 2020), its meaning is often only implicit (Frank, Glikman and Marchini, 2019), and can therefore differ among conservationists (Treves, Wallace and White, 2009; Carter and Linnell, 2016). Where coexistence is explicitly defined, the majority of studies use Carter and Linnell's (2016, p.575) definition: 'dynamic but sustainable state in which humans and wildlife co-adapt to living in shared landscapes, where human interactions with carnivores are governed by effective institutions that ensure long-term carnivore population persistence, social legitimacy, and tolerable levels of risk'. However, some conservationists define coexistence as simply the physical co-occurrence of humans and wildlife in a landscape (Dickman and

Hazzah, 2015). More recently coexistence has been defined as occurring when the interests of both humans and wildlife are satisfied, or when a compromise is negotiated by human stakeholders which allows humans and wildlife to exist together (Frank, Glikman and Marchini, 2019). With these varying definitions, it is clear that coexistence can be interpreted very differently when viewed from either a social or natural science perspective (Carter and Linnell, 2016). Those working solely from a biological perspective may only aim to protect biodiversity which is not the same as trying to promote human–wildlife coexistence (Pooley, Bhatia and Vasava, 2021). Achieving coexistence often involves managing conflicting human interests, values, and actions (Madden, 2004; Redpath *et al.,* 2013). In most cases of coexistence, some negative interactions are expected to remain but qualify as coexistence as long as carnivore species can persist as a self-sustaining population (Chapron and López-Bao, 2016). From a human perspective, this could refer to peaceful coexistence or coexisting while remaining rivals (Frank, 2016). A lack of common definition can lead to opposing and even conflicting conservation priorities and outcomes for different stakeholder groups (Carter and Linnell, 2016).

As coexistence relates to the state of human behaviours it is therefore rooted in psychology. Recently, researchers have become more interested in the factors that motivate behaviour aimed at coexisting (Slagle and Bruskotter, 2019). A variety of social psychology models exist to help understand the processes that influence human behaviour (Muhar *et al.,* 2018) and studies exploring coexistence have begun to apply social science approaches to study human perceptions, attitudes, and behaviour (Treves *et al.,* 2006; Redpath, Bhatia and Young, 2015). For example, the Theory of Reasoned Action (TRA) (Ajzen and Fishbein, 1988; Fishbein and Manfredo, 1992) and Theory of Planned Behaviour (TPB) (Ajzen, 1991; Ajzen and Driver, 1992) suggest that human behaviour is shaped by attitudes, norms and perceptions of control. These models have been applied to the investigation of the human dimensions of HCIs (e.g., Amit and Jacobson, 2017). The TPB explores how the intention to perform a behaviour is predicted by attitude towards the behaviour, subjective norms, external factors and perceived behavioural control (Ajzen, 1991) and is useful for explaining variation in specific behavioural intentions. Therefore, use of the TPB model can provide insights into how interventions increase or decrease tolerance as a behaviour towards species (Slagle and Bruskotter, 2019). The TPB shows that attitudes are just one of multiple factors that determine behavioural intentions and subsequent behaviour (Nilsson, Fielding and Dean, 2019).

Other studies have developed models of human-carnivore tolerance including the wildlife tolerance model (WTM) (Kansky, Kidd and Knight, 2016) and wildlife acceptance capacity (WAC) model (Decker and Purdy, 1988). The WTM is a theoretical framework that aims to determine key variable and drivers of tolerance towards wildlife in coexistence contexts (Kansky, Kidd and Knight, 2016). The WAC model indicates the maximum wildlife population level in an area that is acceptable and has been used to explore levels of tolerance (Bruskotter *et al.,* 2015). Research on acceptance has primarily focused on the extent to which individuals are willing to accept different levels of local wildlife populations (Riley and Decker, 2000; Lischka, Riley and Rudolph, 2008). Wildlife Acceptance Capacity concepts have most commonly been tested by asking participants whether they would like the populations of specific species to increase, decrease, or stay the same. For example, Western *et al*. (2019) asked "What would you like to see happen to the numbers of lions in this area, and why" to provide a quantitative measure of tolerance from questionnaire surveys. However, use of such method does not allow for understanding of the context of participants' views or factors that shape their responses.

To date, the vast majority of psychological research in human-wildlife coexistence scenarios has focused on attitudes towards wildlife (Nilsson, Fielding and Dean, 2019). The term attitude is used to describe a disposition towards an action, issue or event (Manfredo and Dayer, 2004; Fort *et al.,* 2018). Studies exploring the human dimensions of HWI usually involve measuring stakeholder attitudes towards wildlife on the basis that attitudes are predictors of tolerance and behaviours towards wildlife (Dietsch, Manfredo and Teel, 2017; Whitehouse-Tedd, Abell and Dunn, 2020). Attitude has been used as an indicator of coexistence and has typically been measured through questionnaires or interviews with livestock owners. This is likely because it is considered an easier and short-term alternative to assessments of behaviours. However, recently attention has been given to addressing the previously depauperate extent of attitude-behaviour research regarding HCI interventions (e.g., Hazzah *et al.,* 2017; Chausson *et al.,* 2022).

Behaviours are regarded as observable actions (Fishbein and Ajzen, 1977). These acts can have direct and indirect impacts on the achievement of coexistence goals. While attitude and behaviour are linked it is important to remember that they are not synonymous, and therefore reported attitude may not represent behaviour towards wildlife (Dickman, 2010; Liu *et al.,* 2011). Additionally, behaviours can occur without the accompanying attitude and people can behave out of habitat and without thinking about their behaviour. For example, Nudge Theory (Thaler and Sunstein, 2009) shows how people's decision-making processes can be influenced without changing their attitude. Assuming that a change in attitude will be echoed by behaviour may lead to misdirected conservation efforts, particularly if generalised attitudes are used to predict highly specific behaviours (Nilsson, Fielding and Dean, 2019). Despite this, some studies have found that attitude related strongly to self-reported behaviours (Treves, 2012; Bruskotter *et al.,* 2015). However, responses to direct questions about behaviour can be shaped by social desirability biases in which respondents answer questions in a way they think will be viewed favourably by others and consequently undesirable behaviours can be under-reported (Fisher, 1993). It must also be considered whether coexistence goals should be more about accommodating human behaviour as much as (or more than) changing it. Aiming to change human behaviour puts the emphasis on the idea that people are doing something wrong and need to change this, when there could be misunderstandings or misperceptions on the part of the conservation community about what the land users are doing. It could also fail to identify barriers to positive behaviours and the factors that contribute to these barriers. Furthermore, the behaviour may be unavoidable, or legitimate but other factors means it has a negative outcome for wildlife. Such assumptions may be reflective of a bias in conservation literature which frequently focuses on the idea that human behaviour is at fault and requires; change in turn, this exacerbates human-human conflict, rather than increasing coexistence.

Tolerance, in a conservation context, is defined as the acceptance of the perceived costs and benefits of living alongside local populations of wildlife (Bruskotter and Fulton, 2012; Kansky, Kidd and Knight, 2016). It is generally conceptualised and measured in two forms: attitudes (e.g., attitudes toward a species, acceptability of a species) and behaviours (e.g., illegal killing) (St John *et al.,* 2012; Bruskotter and Wilson, 2014; Gebresenbet *et al.,* 2018; Frank, Glikman and Marchini, 2019). As such, tolerance is used in many studies, as an overarching term to encompass beliefs, attitudes and behaviours towards wildlife (Bruskotter and Wilson, 2014). Tolerance towards wildlife has therefore been used by multiple studies as a means of studying people's perceptions of and behaviour towards wildlife (Slagle and Bruskotter, 2019). Whilst measures of tolerance vary greatly, studies of HWI scenarios have usually used self-administered questionnaires or interviews, and often look at tolerance towards a particular species (Slagle and Bruskotter, 2019). In many such surveys, farmers are often asked to rank wildlife perceived as pests to help researchers understand their tolerance of different species (Naughton-Treves and Treves, 2005). Such survey methods may be limiting and make assumptions as to which species may be considered as pests. Furthermore, it has been noted that psychometric scales used to measure attitudes and tolerance towards wildlife have often been used without appropriate validation or reliability testing (Whitehouse-Tedd, Abell and Dunn, 2021). Tolerance has been found to be culturally determined and is dependent on religious beliefs, income, education level and carnivore knowledge (Mkonyi *et al.,* 2017; Gebresenbet *et al.,* 2018). Understanding tolerance is considered important as retaliatory killings usually occur only if depredation exceeds tolerance levels (Gebresenbet *et al.,* 2018). However, it is important to remember that tolerance, measured as a psychological construct, may not translate into behaviour (Frank, Glikman and Marchini, 2019). For example, Dickman (2010) found that retaliatory killings continued after a reduction in livestock predation. Furthermore, use of the term tolerance has been criticised for having negative connotations since by suggesting that a particular species has to be tolerated, it may convey the message that these species do not truly belong to the places they occur (Chapron and López-Bao, 2020).

1.7 Interventions used to facilitate coexistence

Management practices designed to reduce predation on livestock have been used since cattle were first domesticated over 10,000 years ago (Torres, Oliveira and Alves, 2018). Today, the mitigation of negative interactions between humans and carnivores has become a key component of carnivore conservation (Potgieter, Kerley and Marker, 2016). Numerous strategies and practices have been used around the world, largely with the aim of preventing negative interactions from happening in the first place (Ocholla *et al.,* 2013). A significant amount of logistical and financial resources are invested in protecting livestock and carnivores (van Eeden, Eklund, *et al.,* 2018).

Intervention strategies can be divided into two main categories, lethal and non-lethal control. Lethal control methods include hunting, trapping and poisoning (van Eeden, Crowther, *et al.,* 2018). Shooting can be described as a selective lethal method if only known individuals are targeted (Taylor *et al.,* 2016) however, the use of poison is non-selective and its use can have much wider consequences for the ecosystem (Marker, Dickman and Macdonald, 2005). If poisoned carcasses are left out to attract predators, they indiscriminately kill many species that feed on the carcass. For example, poison intended to kill lions in Southern Africa has also been shown to affect species such as vultures, leopards, hyenas and jackals (Funston and Henschel, 2016). The use of poison is therefore particularly concerning given its impacts on scavenger species such as vultures (Plaza, Martínez-López and Lambertucci, 2019). However, of the lethal options, poisoning is the least labour-intensive and therefore likely to continue (Brink *et al.,* 2021), particularly as it is difficult to police.

Illegal killings frequently occur in retaliation for livestock depredation and often take place after carnivores are observed near livestock, or soon after a suspected predation event has occurred (Treves, Krofel and McManus, 2016). Furthermore, losses caused by other factors including theft, disease and accidents are often blamed on carnivores (either intentionally or mistakenly), and can lead to lethal control (Marker, Dickman and Macdonald, 2005). Lethal control methods are often readily available to use and can be perceived as cheaper and more effective than non-lethal methods (McManus *et al.,* 2015). Lethal control may also be used indiscriminately even in the absence of negative HCIs and can continue after depredation has ceased (Dickman, 2010; Torres, Oliveira and Alves, 2018).

Lethal interventions can be implemented legally in some cases (Treves and Karanth, 2003) - for instance some governments conduct or support population culls or killing of recognised problem animals (Ocholla *et al.,* 2013). However, in many places the killing of carnivore species is illegal and conservation law is put in place by the government. For example, during the 1980s South African law removed support for lethal control of predators and restricted the use of poison (Nattrass, Drouilly and O'Riain, 2020). Legislation dictating what people can and cannot do with wildlife (Madden, 2004), including restrictions on the use of lethal control, can leave landowners feeling powerless to protect their livelihoods, potentially giving rise to other socio-political tensions (van Eeden, Crowther, *et al.,* 2018). Additionally, it can exacerbate retaliatory killing as a form of protest against political decisions (Gebresenbet *et al.,* 2018). Where the killing of carnivore species is illegal it can be difficult to obtain estimates of the numbers killed by people, thus further complicating conservation practices (Funston and Henschel, 2016). However, techniques have been developed to explore illegal or sensitive topics. For example, the Randomised Response Technique (RRT) has been used to investigate illegal behaviours towards carnivores in South Africa (St John *et al.,* 2012).

Whilst lethal control methods may provide a temporary reprieve from negative HCIs, they do not provide a permanent solution as the methods do not address the cause of the problems (Boronyak, Jacobs and Wallach, 2020). In some scenarios the conducting of retaliatory killings may be understandable, nevertheless lethal control undermines conservation efforts for both carnivores and the broader ecosystem (Lennox *et al.,* 2018). The killing of carnivores can fragment social groups or create gaps in the ecological community causing meso-carnivore release (Green *et al.,* 2018). In turn, these meso-carnivores may also prey on livestock (Treves, Krofel and McManus, 2016). Additionally, removal of territory holders can create a vacuum that is rapidly filled by neighbouring individuals or dispersers (du Toit, Cross and Valeix, 2017). Where lethal control is carried out by multiple people in an area, it can lead to large-scale population declines (Hanley, 2015). Lethal control has become one of the most serious threats to the survival of carnivores and has resulted in the extirpation of many carnivores from their historical ranges (Kissui, 2008; Loveridge, Valeix, *et al.,* 2017).

In some places, the use of lethal control is increasingly socially unacceptable (Potgieter, Kerley and Marker, 2016). Despite this, a desire to reduce carnivore populations may remain - particularly for those experiencing negative interactions (Lennox *et al.,* 2018). In places where societal values and policies have changed, the almost exclusive use of lethal control has given way to the use of non-lethal interventions alongside, or as replacements to, lethal methods (van Eeden, Eklund, *et al.,* 2018). The use of non-lethal methods is more likely to be compatible with conservation objectives and less likely to cause the exclusion of large carnivores or counter-productive ecological consequences (McManus *et al.,* 2015). However, it is argued that many livestock owners implement intervention strategies without considering their effectiveness in reducing predation, related threats or ecological degradation (Treves, Krofel and McManus, 2016).

Various non-lethal control methods have been developed to reduce or prevent negative HCIs and typically focus on deterrents, enclosures and improved husbandry practices (Boronyak, Jacobs and

Wallach, 2020). The main non-lethal predator control methods used by livestock farmers include livestock guardian animals including dogs, llamas and donkeys, the installation or electrification of fences, use of kraals/camps, shepherds, lighting, fladry, hazing, livestock protection collars and disturbance through shouting, torches and shots (McManus *et al.,* 2015; Torres, Oliveira and Alves, 2018; van Eeden, Crowther, *et al.,* 2018). Compensation schemes for livestock loss have also been used globally by organisations and governments with the intentions of reducing the economic impacts of depredation and increasing tolerance of wildlife. However, the use of compensation schemes can have other consequences including neglecting to use other preventative measures and farmers becoming dependent on payments (Dickman, Macdonald and Macdonald, 2011). Reliance on such schemes can be problematic as they often depend on external funding which can run out and schemes abruptly end (Bulte and Rondeau, 2005). Payments can take a long time to be processed and may not reflect the full market value of the animal lost. They are also problematic for illiterate or rural farmers, who may struggle to fill in the claim forms or have difficulties accessing the schemes, e.g., needing to travel long distances to submit paperwork (Barua, Bhagwat and Jadhav, 2013). Additionally, the use of compensation schemes may encourage farm labourers to migrate back to rural areas resulting in more land being cleared for agricultural purposes and overgrazed areas (Bulte and Rondeau, 2005). Such migration can create poverty traps in areas where compensation schemes exist (Dickman, Macdonald and Macdonald, 2011). As such, the offering of financial incentives for livestock loss needs to be carefully considered, and must satisfy the economic and cultural needs of all parties involved (Redpath *et al.,* 2013).

The majority of non-lethal interventions focus on reducing the visible impacts of negative interactions such as livestock loss (Barua, Bhagwat and Jadhav, 2013). As such, interventions tend to focus on predator management rather than livestock management (Chapron and López-Bao, 2020). Although herd management practices can be changed to decrease livestock loss, arguably they are less often considered as intervention strategies (Chapron and López-Bao, 2020). That said, changes to husbandry practices can be implemented and may include human guarding, guard animals, removal of ill or injured stock and changes to grazing practices, e.g., tightly herding. Where carnivores are reduced or eradicated, it can lead to the abandonment or replacement of traditional livestock husbandry practices (van Eeden, Crowther, *et al.,* 2018). Livestock are then left to graze unsupervised over much larger areas arguably causing greater environmental and ecosystem damage (Linnell *et al.,* 1996). In parts of Europe, this caused issues when carnivores such as bears and wolves were reintroduced or recovered as livestock were unprotected and people no longer employed traditional methods which would permit them to live alongside carnivores (Gehring, Vercauteren and Landry, 2010). Consequently, the recovery of carnivore populations in many parts of Western Europe has led to the reintroduction or rediscovery of livestock guardian dogs (LGDs) (Gehring, Vercauteren and Landry, 2010). The use of methods such as LGDs represents the re-adoption of traditional protection methods that were historically used throughout Asia and Central, South, and Eastern Europe (Gehring, Vercauteren and Landry, 2010; Ivaşcu and Biro, 2020).

The main rationale for intervention use is that if interventions can reduce the impact of carnivores on livestock, acceptance of carnivores is theorised to increase (Eklund, Johansson, *et al.,* 2020). It is largely suggested that effective interventions will lead to a reduction of livestock depredation and reduced persecution, thereby benefiting both humans and carnivores (Hazzah *et al.,* 2014; Lichtenfeld, Trout and Kisimir, 2015; Miller *et al.,* 2016). Therefore, in order to achieve the desired outcomes, interventions need to be effective in reducing attacks on domestic livestock as well as concurrently eliciting a change in human behaviours and attitudes towards carnivores. Despite the prevalence of interventions aimed at reducing predation on livestock, there is little consensus about the results or whether reduced rates of predation lead to greater tolerance of carnivores, and this has not yet typically proved to be a justified cause-effect relationship (Miller *et al.,* 2016; Western *et al.,* 2019). Furthermore, a large difference can be seen between the number of intervention strategy recommendations made by researchers and the number of those whose efficacy at achieving desired goals has actually been studied or systematically evaluated (Holland, Larson and Powell, 2018).

1.8 Defining conservation success

In order to effectively use conservation resources to increase coexistence there is a need to identify and understand which approaches are most likely to succeed (Kapos *et al.,* 2009). Particularly where livelihoods and species survival are at risk, it is vital that resources are used for approaches that can be proven to be successful (Sutherland *et al.,* 2004; Kapos *et al.,* 2009). Given that there are many forms of and pathways to success (Phillis *et al.,* 2013) defining success can be difficult (Wells *et al.,* 1992). Defining success is further complicated by an increase in the scale of conservation initiatives and the diversity of desired outcomes (Thomsen and Caplow, 2017).

Traditionally, conservation success has been defined as the meeting of biophysical goals, for example species protection and habitat restoration (Thomsen and Caplow, 2017). The Cambridge Conservation Forum used a participatory process to explore the issue of evaluating conservation success (Kapos *et al.,* 2008). The framework developed by the Cambridge Conservation Forum defines successful conservation as "increasing the likelihood of persistence of native ecosystems, habitats, species, and/or populations in the wild (without adverse effects on human well-being)" (Kapos *et al.,* 2008 p.157).

Success can be defined differently according to scale (temporal, spatial, institutional) as well as context (Cooke *et al.,* 2020). As a result, success can be viewed and prioritised differently by stakeholder groups (Cooke *et al.,* 2020). Arguably, some conservationists view the increase in a population of a species of conservation concern as a success, irrespective of the cost to or perspectives of other parties (i.e., success for farmers may not be the same as success for conservationists) (Redpath *et al.,* 2013). Perhaps as a result of this perception, the use of scientific research and evidence forms the basis of many conservation decisions (Freckleton, 2020). The typical aims of scientific practices are to find solutions that are as robust as possible and therefore, conservation scientists evaluating the success of an intervention strategy will look at whether, on average, there is evidence of its effectiveness and the mechanisms that drive this (Freckleton, 2020). However, achieving measurable scientific effectiveness is just one component of conservation outcomes and economic, social and political considerations also play a role and contribute to overall, and long-term, success (Pullin *et al.,* 2013). A such, it has previously been suggested that there are four main outcomes that should be used to measure conservation success: attitudes, behaviours, economics and biological changes (Waylen *et al.,* 2010). More recently, there is growing recognition that understanding and changing human behaviour is often critical to achieving conservation goals (Reddy *et al.,* 2017; Milner-Gulland *et al.,* 2020).

1.9 Measuring conservation success

Despite the need, measuring conservation success is often difficult (Kapos *et al.,* 2009), with some even going as far as claiming that defining and measuring success in conservation is "mission-impossible" (Sawhill and Williamson, 2001). Success is often measured in terms of the ultimate outcomes, i.e., did the research address the key science needed to inform action to resolve or mitigate an environmental problem (Wall, McNie and Garfin, 2017). However, rigorous and high-quality scientific research alone is insufficient to measure success in an environmental context. Achievement of conservation success can depend on increasing public awareness about a given issue intended to alter human behaviour (Selinske *et al.,* 2018; Nilsson, Fielding and Dean, 2019). Where improving environmental outcomes depends on changing human behaviours, measuring and achieving success is likely to take a long time (Nilsson, Fielding and Dean, 2019). In other scenarios, success may simply be providing advice to decision-makers. Furthermore, success may occur to varying extents, for example, a change in attitude but not behaviour may be considered a success on a lower scale. Communication of research outcomes is arguably a key component of measuring success. If findings are communicated, but end users cannot access the data or peer reviewed papers, findings are likely to be ignored (Cook *et al.,* 2013). Additionally, peer reviewed research that is not communicated or delivered to appropriate stakeholders contributes little to resolving environmental problems

(McKinley, Briggs and Bartuska, 2012). Research therefore cannot be considered successful if it does not reach those for who the research was intended to impact.

Considerable effort has been invested in developing frameworks that help to monitor the progress and success of conservation projects (Sutherland *et al.,* 2004; Kapos *et al.,* 2008). There are a number of approaches which have been used. One example is the Theory of Change (Center for Theory of Change, 2018), which shows how a project can reach its desired goals through different pathways of change. The Theory of Change describes the logical and ordered sequence of interventions, actions and outcomes identified during the planning process. These indicators can be tested, thereby supporting evaluation of a project's success or failure. This can be used by both internal and external users to understand what is working (Milner-Gulland *et al.,* 2020). The Cambridge Conservation Forum applies a stepwise model of how projects proceed and recognises that conservation projects usually involve a variety of activities which have to be measured by different outcomes (Kapos *et al.,* 2008). Despite the development of these frameworks, it is evident that there are still inadequate mechanisms in place to assess the success of interventions used in many conservation projects (Altringham, Berthinussen and Wordley, 2020). As such, there remains an urgent need for robust evaluations of the success of conservation interventions (Milner-Gulland *et al.,* 2020).

1.10 Application of success measures to coexistence interventions

There is considerable research documenting the implementation of interventions designed to increase human-carnivore coexistence. However, there have been few attempts to document the success of these intervention strategies (Miller *et al.,* 2016; van Eeden, Eklund, *et al.,* 2018; Khorozyan and Waltert, 2019; Khorozyan, 2020). The understanding of intervention strategy success has largely been built on narrative reviews (Eklund *et al.,* 2017), with early studies focused on discussing the relative advantages and disadvantages of different techniques (Miller *et al.,* 2016). Current evaluations of interventions predominantly measure (or use recalled reports of) livestock loss before and after the implementation of different strategies (Miller *et al.,* 2016; Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018). In all studies reviewed by Miller *et al.* (2016) the success of each intervention trial was determined in terms of the reduction in number of livestock lost, or the potential for an attack after techniques were applied. Similarly, Holland, Larson and Powell (2018) found that the most common measure to determine effectiveness was reduction in livestock loss. Whilst this has emerged as a common measure and definition of intervention success, livestock loss has also been reported in a number of different ways e.g., numbers of livestock loss, percentages of income and percentage of livestock lost to predators (Inskip and Zimmermann, 2009). Furthermore, there are a number of limitations to these current approaches to measuring intervention success. These include oversimplified equating of levels of damage with levels of conflict and unsuccessful technical fixes resulting from failure to engage locals, address hidden costs, or understand cultural causes of negative HCIs (Pooley *et al.,* 2017). As such, many intervention methods have proven to be inappropriate at achieving goals, for example, implementation of fences which are not maintained or building of kraals which are not culturally acceptable (Madden, 2004; Torres, Oliveira and Alves, 2018; Weise *et al.,* 2018). Thereby, simply implementing a conservation-focused intervention does not guarantee ecological success or benefits to humans (Bennett, 2016).

Evidence-based conservation has been used as a method to analyse the effectiveness of interventions designed to reduce negative HCIs (Altringham, Berthinussen and Wordley, 2020). The term evidence-based effectiveness is used to describe whether the intervention has been evaluated through quantitative evidence based on experimental work using treatment (interventions) and control (without interventions) samples (van Eeden, Eklund, *et al.,* 2018). Such experiments allow for comparisons before and after the intervention and comparisons with and without the intervention (Khorozyan, 2020). Experimental tests allow the estimation of effectiveness of interventions through various metrics such as relative risk (Eklund *et al.,* 2017; Khorozyan, 2020), odds ratio (Eklund *et al.,* 2017), magnitude of change (Miller *et al.,* 2016; Khorozyan, 2020) or Hedges' d (van Eeden, Crowther, *et al.,* 2018). Hedges' d is an estimate of the standardised mean difference between control and treatment, it accounts for variation in study effort so that it is not biased by small sample sizes (Hedges and Olkin, 1985). Estimations of evidence-based intervention effectiveness are very sporadic and meta-analyses aiming to make broad inferences only began appearing in the literature recently (Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018; Khorozyan and Waltert, 2019, 2021). However, the conducting of such controlled experiments is unlikely to be feasible or ethical in many field scenarios. The realities of conservation practice (e.g., limited resources and urgency) mean that most interventions are implemented and trialled without an explicit control study. Interventions are often sought when problems are at their most severe or tolerance levels exceeded, and therefore users may not be willing to take part in control studies. As a result, it is usually impossible to measure or demonstrate success relative to what would happen without the intervention (Pullin *et al.,* 2013). Furthermore, use of evidence-based effectiveness may be interpreted by intervention users as assuming superiority of scientific methods over local perceptions to determine success, which may exacerbate tensions between stakeholders, as documented by Terblanche (2020).

Studies investigating and evaluating the success of LGDs have primarily used farmer-reports of livestock loss before and after the placement of a LGD (Marker, Dickman and Macdonald, 2005; Potgieter *et al.,* 2013; Rust, Whitehouse-Tedd and MacMillan, 2013; Leijenaar, Cilliers and Whitehouse-Tedd, 2015; van der Weyde *et al.,* 2020). In these studies, farmer perceptions of LGD success were obtained through conducting interviews and questionnaires. Such reports are usually based on retrospective recall rather than prospective recording and are therefore labelled as perceived effectiveness. Questioning farmers about the performance of their dogs could be regarded as a subjective way of determining success that reflects farmer perceptions and not the actual efficacy of the dog (Marker, Dickman and Macdonald, 2005). Studies using farmer reports to determine reduction in livestock loss and intervention success have been criticised for relying on recall and it is argued that perception alone cannot determine success (Ohrens, Santiago-Ávila and Treves, 2019; Khorozyan and Waltert, 2021). Furthermore, the study by Marker, Dickman and Macdonald (2005) did not collect data to evaluate whether the placement of the LGD directly affected the use of lethal predator control on farms. Whilst it is rare for intervention evaluations to examine changes in tolerance or behaviour towards wildlife, a few studies have, (e.g., Rust, Whitehouse-Tedd and MacMillan 2013; Horgan *et al.* 2020). Additionally, some research has demonstrated links between levels of livestock loss and levels of predator removal (Ogada *et al.,* 2003; Shivik, Treves and Callahan, 2003). This suggests that whilst perceived reduction in livestock loss may not directly correlate with increasing tolerance for carnivores, it is probably a key indicator (van Eeden, Crowther, *et al.,* 2018). Moreover, it has been found that perceptions of LGD success was correlated with witnessing attentiveness, trustworthiness and protectiveness of LGDs, rather than livestock loss (Potgieter *et al.,* 2013).

If intervention strategies aim to increase coexistence through an assumption that reduced livestock loss will reduce persecution of carnivores, measures of success need to consider both biological effectiveness and changes in human behaviour or attitude (van Eeden, Eklund, *et al.,* 2018; Eklund, Johansson, *et al.,* 2020). Intervention use should ideally also mitigate social conflicts over carnivore presence (Kaplan-Hallam and Bennett, 2018). Therefore, to achieve coexistence, interventions need to be supplemented with strategies that address any underlying human and ethical facets more directly (Carter and Linnell, 2016). Measures of success should subsequently also consider the human aspect of intervention use. However, very few studies measure both biological effectiveness and the human dimensions. Conservation scientists' familiarity with statistical quantification over interdisciplinary methods helps to explain the overwhelming focus on evaluation using more easily quantifiable measures such as livestock loss (Pooley, Bhatia and Vasava, 2021). However, providing scientific evidence of success may not necessarily address conflicts of interest between conservationists and livestock farmers, and has the potential to generate further contention (Redpath, Bhatia and Young, 2015). Such tensions can arise when different stakeholders do not share perceptions of which interventions are acceptable and which are not (Redpath, Bhatia and Young, 2015; Eklund, Johansson, *et al.,* 2020). Neglecting stakeholders can lead to an incorrect assessment of intervention success in terms of achieved levels of equitable participation and efficiency (Gore and Kahler, 2012). However, Holland *et al.,* (2018) note that whilst community involvement in decision making is often recommended, its role in implementation success is rarely evaluated.

Overall, there is a clear lack of consensus in the literature as to how intervention success is best measured and who should determine success. Such discrepancy may stem from a lack of consensus on the definition of conservation success. Despite this, it is agreed that successful interventions aim to mitigate conflicts between people with interest in conservation and those with interest in animal husbandry and productivity. However, behavioural and attitudinal changes are rarely included in evaluations. To further complicate measures of success, it is becoming clearer that there is no one-size fits all intervention strategy and therefore success is also likely to be highly contextualised and cannot be generalised, as highlighted by Zimmermann *et al.,* (2021). Stakeholder involvement in measuring success is necessary to increase the acceptance of research results and ensure continued use of interventions. In spite of this need, there are no current studies that explore stakeholder perceptions of success of livestock depredation intervention strategies. Understanding stakeholder perceptions of success and accommodating or adapting the intervention towards, or even changing perceptions in order that the intervention becomes feasible, is necessary to ensure the long-term sustainability of any intervention designed to increase coexistence.

1.11 Thesis aims and outline

A lack of HCC is a major concern for conservation and farmer alike. Increasing coexistence between carnivores and communities is critical to the survival of many large carnivore species and vital for human livelihoods. The ultimate aim of any HCC intervention is the mitigation of the cause of contention (often livestock predation) to the point that both human and wildlife interests benefit. As such, achievement of HCC goals requires the effective removal of (perceived or real) barriers to coexistence; thus, the success of intervention strategies needs to be known. To evaluate an HCC strategy's success, stakeholders' perspectives on coexistence and strategy effectiveness, and their behaviour towards carnivores must be known. However, this holistic approach is rarely conducted and is currently poorly documented in the scientific literature. Subsequently, perceptions of the success of HCC strategies currently utilised is unknown, and opportunities to improve and enhance promising strategies are being missed. Understanding stakeholder perceptions of HCC interventions and success will enable incorporation into conservation practice which is likely to improve intervention engagement. The thesis presented here addresses this lack of research through a mixed method study exploring various stakeholder perceptions of HCC in the Limpopo Province, South Africa. The study will focus on perceptions and measures of success pertaining to interventions designed to increase

HCC. By exploring similarities and differences between stakeholder groups and generating recommendations for future evaluations of intervention success based on stakeholder experience, this thesis sets out to address a knowledge gap in HCC.

The overarching aims of this study are to:

- Investigate how success is perceived by stakeholders during HCC intervention programmes.
- Understand the importance of stakeholder factors in facilitating coexistence.
- Identify similarities and difference between stakeholders regarding intervention success and coexistence.
- Generate recommendations for future evaluations of HCC interventions.

Chapter 1 provides background information on the context of the study and why exploring various stakeholder perceptions is essential in HCC scenarios. In chapter 2 grounded theory interviews and participant observation were used to explore the perceptions of key stakeholders involved in HCC scenarios to understand the factors that shape their relationship with carnivores and how these may impact HCC.

Chapter 3A comprises a published examination of participant measures of intervention success and whether coexistence as a concept was considered feasible. In chapter 3B participant perceptions of specific intervention strategies were explored and factors reported to contribute to perceived success or failure are identified.

In chapter 4, interview and camera trap data were evaluated simultaneously to explore areas of similarity, contrast, and synergy in regard to carnivore presence, frequency of visits and livestock-carnivore interactions.

In chapter 5, a Q-method survey was conducted using stakeholder measures of and factors contributing to success determined in chapter 3A. The survey revealed similarities and differences between stakeholders regarding priorities for measures of intervention success. The final chapter (chapter 6) syntheses the findings of chapters 2-5 and discusses these findings in the wider context of the study. This chapter provides recommendations for future implementations of HCC interventions and evaluations of intervention success.

Positionality Statement

In planning and doing this thesis, it was essential to reflect on my position as a researcher. I am a white, British female who conducted my research in rural South Africa and within a predominantly Afrikaans speaking farming community. I hereby acknowledge that, to some extent, my positionality influenced the relationships and responses of participants as well as my interpretation of the data. I conducted my master's research in the same geographical area, this previous work provided much insight into how best to engage with farmers to discuss wildlife and conservation issues, as well as an understanding of cultural etiquette of the area. In addition, I have a background in biological anthropology which provided exposure to and experience in both biological and social research methods. A as result, l had an awareness of the role of reflexivity in interpretation and the need to understand the participants through cultural relativism. Cultural relativism is the principle in which an individual's beliefs and activities should be understood in terms of that individual's culture (Tilley 2000). Therefore, cultural relativism accepts that people view the world through their own cultural lens and make judgements in accordance with their own social and cultural norms. I kept this in mind throughout my fieldwork and data analysis to better understand and interpret the data. Likewise, a mixed-method approach was adopted for the study, this enabled a more holistic, in-depth understanding of participants perceptions that would not have been possible through reliance on a single method (e.g., semi-structured interviews). This was deemed particularly important given the multi-faceted nature of human-wildlife interaction scenarios.

Chapter 2: Exploring the context, drivers and barriers to human-carnivore coexistence for key stakeholders

2.1 Introduction

The successful conservation of large carnivores ultimately depends on the tolerance and behaviour of the people living within their ranges (Bruskotter and Wilson, 2014). The relationship between humans and carnivores is influenced by a wide range of factors including age, education, wealth, culture, religion, knowledge of carnivores, concern over safety, benefits derived from wildlife, past experiences and experience with conservation authorities (Lagendijk and Gusset, 2008; Bennett, 2016; Gebresenbet *et al.,* 2018; Bickley *et al.,* 2019). Human attitudes and behaviours towards carnivores result from complex interplay between these social, emotional, cognitive and cultural contexts (Carter and Linnell, 2016; Gebresenbet *et al.,* 2018). In order to understand the factors that shape people's relationship with carnivores there is a need for research to identify the social, cultural, historical and political drivers of the interactions (Holland, Larson and Powell, 2018). Subsequently, the perceptions and attitudes of people living alongside carnivore species need to be assessed and understood to determine what behavioural and attitudinal changes may be undesirable (conflict) or desirable (coexistence) (Bickley *et al.,* 2019; Skogen *et al.,* 2019).

In recent years, studies exploring perceptions have gained relevance in human-carnivore coexistence (HCC). Bennett (2016) define perception as "the way an individual observes, understands, interprets, and evaluates a referent object, action, experience, individual, policy, or outcome" (p. 585). Perceptions of wildlife are very localised (Gandiwa *et al.,* 2013), and therefore groups and individuals in the same place can perceive the same situation in very different ways (Bennett, 2016). Perceptions are not necessarily objective, and the construction of perceived realities can produce different interpretations of the same facts (Ballejo, Plaza and Lambertucci, 2020). People's perceptions may change over time, and it is important to understand the factors that may lead to changes, either positively or negatively. Studies of perceptions can therefore provide local insights into the positive and negative interpretations and understandings of conservation initiatives (Bennett, 2016). Consequently, understanding the local context including drivers and barriers to HCC is crucial for reducing negative interactions and implementing appropriate conservation policies.

This chapter explores the perceptions of key stakeholders involved in HCC intervention scenarios to understand the factors that shape their relationship with carnivores and how these may impact HCC. A grounded theory approach was used to conduct and analyse interviews with key stakeholders involved in HCC intervention scenarios. Grounded theory is an iterative, inductive framework developed by sociologists Barney Glaser and Anselm Strauss (1967). In contrast to deductive methods of generating data from theories, grounded theory allows for concepts and categories to emerge from the data (Glaser, 1978). The identified concepts and categories are then linked to form formal theories (Bernard, 2017). The overall aim is to generate a theory as an explanation for processes and actions about issues that impact on livelihoods and wellbeing (Horton *et al.,* 2017). Unlike most other research methods, the processes of data collection and analysis are merged, with the research moving back and forth between the two processes to ground the analysis in the data. The ultimate aim of this movement is to reach theoretical saturation. The process of grounded theory has been much debated and today there are four schools of thought in the debate - Glaserian, Straussian, Charmazian and Clarkeian. Each have four unique methodological systems and debate continues as to where description ends and theory begins (Apramian *et al.,* 2017). Charmaz makes two methodological choices that distinguishes her version of grounded theory from Glaser's and Strauss's, namely the importance of gerund-based coding and playing down the importance of single core categories (Apramian *et al.,* 2017). Charmaz (2006) agrees with Glaser's approach of keeping initial codes open ended but also acknowledges that the researcher does hold prior knowledge. This study adopted a constructionist Charmazian approach to grounded theory which acknowledges that the researcher holds prior knowledge and theory arises from reflexive interactions between the researcher and participants (Charmaz, 2006).

The process of grounded theory begins with an open-ended research question that identifies the topic but does not make assumptions about it. Thus, the research does not begin with a hypothesis or theory but starts by collecting data in the setting (Corbin and Strauss, 1990). Rather than using probability sampling, a theoretical sample of informants is sought to provide diverse perspectives on the topic (Vaccaro, Smith and Aswani, 2010). Once transcribed, interviews are coded; coding is regarded as a core process and it is through coding that theories begin to emerge and develop (Holton, 2007). Coding in a constructionist Charmazian approach begins with initial coding using gerunds and sticks closely to the data to describe what is happening. The use of gerunds helps turn actions into topics thereby encouraging analysis from the perspective of the participants by stating their actions (Charmaz, 2006). The data are then continuously interrogated until the theory emerges (Charmaz, 2006). Initial coding is followed by focused coding, this is the selective phase of coding in which repetitive or significant codes are identified and the researcher starts to sort, synthesise, integrate and organise data. Focused coding advances the theoretical direction of the study by making codes more conceptual. The final stage of coding is theoretical coding, this is the most crucial stage which involves relating categories and theorising about those relationships (Urquhart, 2012). Alongside coding, analysis occurs through conceptual memoing. Memos are theoretical notes about the data and the conceptual connections between categories (Holton, 2007). Memo writing (memoing) is a continuous process and one that is essential to grounded theory. Memos are regarded as the methodological link through which the researcher transforms data into theory (Lempert, 2007). Memos capture the journey of the emerging theory and help to guide further steps in data collection, coding and analysis (Holton, 2007).

There is much debate within grounded theory as to how theory is defined, constructed, and develops. As a starting point, theory can be considered to 'state relationships between abstract concepts and may aim for either explanation or understanding' (Thornberg and Charmaz, 2012, p.41). In constructivist grounded theory, theorists aim for an abstract understanding of studied life and view their analyses as located in time, place, and the situation of inquiry (Charmaz, 2006). In this approach, theory is emerging from and is situated in the researcher's interpretation of the participants. Preconceptions held by the researcher may therefore impact on how the research is interpreted (Charmaz, 2006). In contrast, substantive theory is defined as a theoretical interpretation or explanation of specific conditions or causes (Charmaz, 2006). It is substantive in the sense that it pertains only to the phenomena being studied and makes no claims to generalise beyond that phenomenon (Urquhart, 2012). This study set out to explore a specific phenomenon and condition; the perceptions of the success of intervention strategies designed to increase human-carnivore coexistence. The study explores and provides new insight in this area. However, it was not in the scope of the study aims to develop a formal theory. As shown, grounded theory is inherently flexible and has various possibilities in respect to data sources, methods and the format of generated theory (Birks and Mills, 2022). Furthermore, it is argued that grounded theory does not have to be used as a way of building theory and can be used as a standalone method of qualitative analysis (Urquhart, 2012). The study aimed to produce tangible recommendations that could be applied in practice, rather than generate theories. The findings of the study are therefore presented in a way that was deemed most suitable to the discipline and target audience (e.g., conservation biologists/researchers, conservation practitioners and livestock farmers).

Whilst the use of grounded theory is not limited to a specific discipline (el Hussein *et al.,* 2014), it is not a commonly used method in HCC studies. This study joins a limited number of previous studies using grounded theory in the context of HCC (Rust, 2015; Margulies and Karanth, 2018; Bogezi *et al.,* 2019). The use of grounded theory highlights the individual nature of experiences of carnivores and the numerous factors that may shape the perceptions of those living and farming within the same community. Furthermore, the use of grounded theory allows the testing of hypotheses and generation of theories that emerge from the data into order to explore how and why these perceptions may exist.

This chapter aims to:

- Explore perceptions of carnivores and HCC, based on lived experiences.
- Determine the context, drivers and barriers to HCC for key stakeholders
- Explore self-reported measures of human carnivore interactions (HCI) to gain an understanding of key stakeholder perceptions

2.2 Methods:

This chapter utilises data from key informant interviews, semi-structured interviews and participant observation.

2.2.1 Study area

The study was conducted in the Capricorn and Vhembe Districts of the Limpopo Province (Figure 2.1). Limpopo is one of nine provinces in South Africa and lies at the very north of the country bordering Botswana, Zimbabwe and Mozambique. Limpopo has a population of approximately 5 799 090 (StatsSA, 2016). The Limpopo province is divided into five district municipalities with are further divided into 22 local municipalities (StatsSA, 2016). The five districts are Mopani, Vhembe, Capricorn, Sekhukhune and Waterberg; data collection occurred in the Capricorn and Vhembe districts. In the Capricorn district data collection took place in the Blouberg local municipality. In Vhembe district data collected occurred in the Makhado and Musina local municipalities. The research was conducted using the Alldays Wildlife and Community Research Centre (AWCRC) situated in Blouberg local municipality as a base. Livestock farming participants lived within 100km of AWCRC.

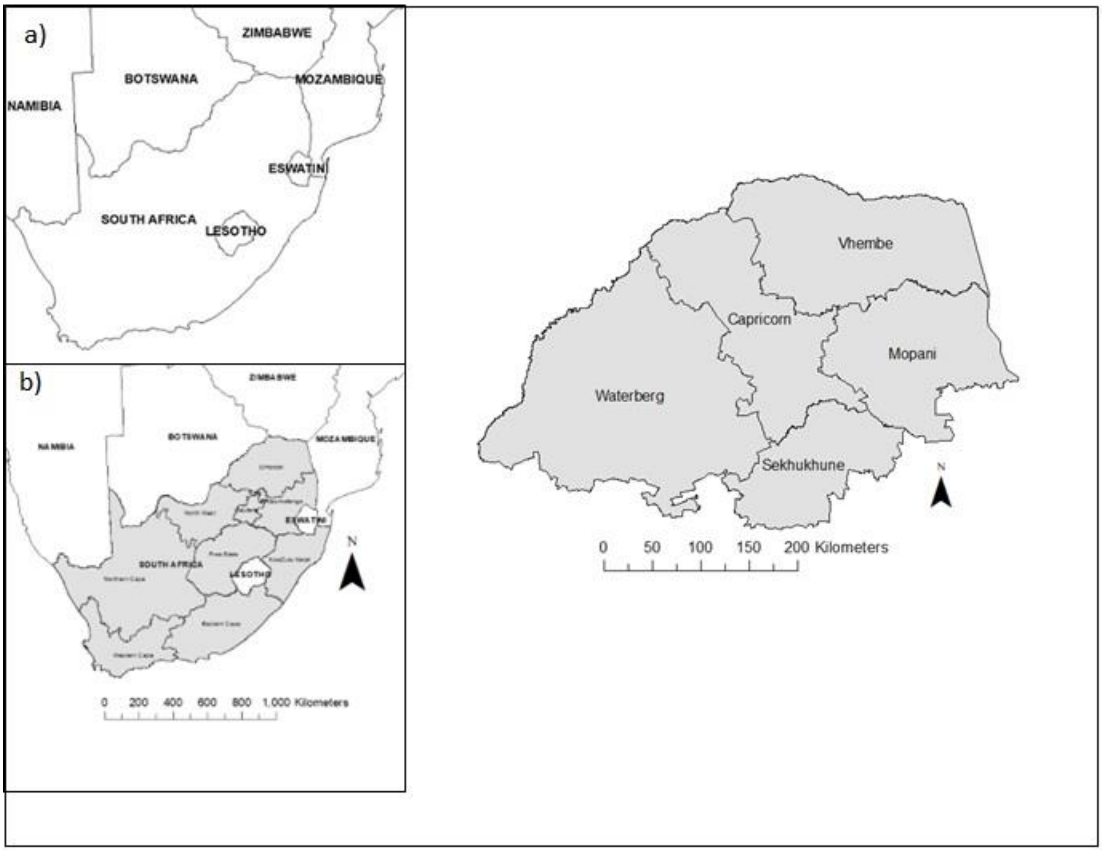

Figure 2.1: Location of the Capricorn and Vhembe districts within the Limpopo Province, South Africa, where data collection occurred. Inset map a) shows the location of South Africa within Southern Africa and b) shows the location of the Limpopo Province within South Africa.

Within South Africa livestock farming is the largest agricultural sector making up 47% of South Africa's agricultural GDP, and contributing substantially to food security (Meissner, Scholtz and Palmer, 2013). Limpopo is an agricultural province and a major contributor to the South African agricultural sector; the main agricultural activity is poultry production (>154,000 households), followed by livestock (>151,000 households) and fruit production (>128,000 households) (StatsSA, 2016). South Africa is described as having a dualistic economy comprising both large commercial farms and small subsistence farms (Grwambi *et al.,* 2006). This dualistic economy can be seen in the study area where agriculture is one of the main means of employment. Subsistence farming is practised in all sectors of society whilst the commercial farms tend to be run by the small percentage of white Afrikaans- and English-speaking farmers (Blouberg Local Municipality, 2014). Livestock farming in the study area involves cattle, goat and sheep.

The area has a semi-arid climate and is prone to frequent drought (mean temperature over the study period was 25.4°C ± 2.9), with the far northern and southern regions of the province being particularly vulnerable to climate change (Anon, 2016). Annual rainfall in the province ranges from 200 millimetres (mm) in the hot dry areas to 1500 mm in higher rainfall areas (Anon, 2016). The majority of rain falls during the summer months (October to April). Limpopo contains three UNESCO biosphere reserves- Waterberg biosphere reserve, Kruger to Canyons biosphere and Vhembe biosphere reserve (Pitman *et al.,* 2017a). The study area falls in the Vhembe biosphere reserve which includes Mapungubwe National Park and Mapungubwe Cultural Landscape World Heritage Site, the Makgabeng Plateau and the Blouberg and Soutpansberg mountain ranges (*UNESCO MAB Biosphere Reserves Directory.*, 2016). Formal protected areas cover 11% of Limpopo (Anon, 2016). The province is known for its rich biodiversity which supports approximately 152 species of mammals (*UNESCO MAB Biosphere Reserves Directory.*, 2016). Carnivore species present in the province include leopard (*Panthera pardus*), brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta crocuta*), cheetah (*Acinonyx jubatus*), caracal (*Caracal caracal*), serval (*Leptailurus serval*), African wild dog (*Lycaon pictus*), black-backed jackal (*Canis mesomelas*), bat- eared fox (*Otocyon megalotis*), honey badger (*Mellivora capensis*), African civet (*Civettictis civetta*), African wild cat (*Felis silvestris*), large spotted genet (*Genetta tigrina*), small spotted genet (*Genetta genetta*), slender mongoose (*Galerella sanguinea*), banded mongoose (*Mungos mungo*), dwarf mongoose (*Helogale parvula*), and Cape clawless otter (*Aonyx capensis*) (Findlay, 2016).

2.2.2 Ethical considerations

The project was approved by the Nottingham Trent University School of Animal, Rural and Environmental Sciences Ethical Review Group (ARE845, ARE880).

Upon meeting with the participants, the project was explained, including relevant ethical considerations. It was made clear that all responses were voluntary and confidential, and that all data would be anonymised and stored securely. The interviews explored topics that were potentially sensitive, therefore participants were informed that any data provided would be anonymised and used for research purposes only. The interview did not proceed unless the participant agreed and signed the consent form provided (Appendix 1). All participants were given an information sheet which included details about the project and explained their right to withdraw within a specified timeframe and the process to follow for withdrawal. The information sheet assigned each participant a unique identifying (ID) code according to their stakeholder group. For interviews that were conducted remotely (i.e., via MS Teams or Skype), the consent form was read out to participants prior to the interview and informed consent was verbally obtained. These participants were also sent a digital copy of the consent form following the interview. With permission from the participant, all interviews were recorded on a Dictaphone or using the video call built-in software. Audio recordings were deleted from the device or software once downloaded to secure storage and saved using the participants' ID code for anonymity. All quotes used in the study are anonymised.

2.2.3 Participant recruitment

The participants in the study were selected with the aim of including a range of stakeholders involved in HCC scenarios. These included livestock farmers, conservation non-governmental organisations (NGO) workers and protected area authority staff (PAA), Table 2.1 outlines stakeholder inclusion criteria. The classification groups were based on the participants employment type and not their values, beliefs or ethos. It is acknowledged that some farmers will also undertake conservation work or hold conservation beliefs, whilst some conservation workers will also farm.

Key informants:

The use of gatekeepers, a person or institution that is in a position to establish connections and/or give permission for the research (Newing, 2011), was employed initially to identify potential participants from each stakeholder group. The research manager and farm owner at AWCRC were already known to the researcher through previous volunteer work involving conducting crop-raiding mitigation trials on crop farms. This work also provided the researcher with an insight into how to engage with farmers and the cultural etiquette of the area. The research manager at AWCRC therefore acted as a key gatekeeper helping to identify initial participants. For the key informant interviews, purposive sampling was used to select participants who had specialist knowledge and/ or insights of the subject and area. Purposive sampling is a recruitment technique used to find key informants with specific required knowledge or experience of a subject, since randomly selected people cannot be expected to become trusted or reliable informants (Bernard, 2017). Key informants from the farmer and NGO stakeholder groups were identified by the researcher with guidance from the gatekeeper at AWCRC and invited to participate in the study. Upon acceptance of the invitation to participate, a meeting was arranged and potential key informants were engaged in a conversation about their thoughts on the interactions that occur between carnivores and livestock farmers. Whilst including a member of all stakeholder groups of interest would have been ideal at this stage, this was not possible due to limited numbers in the wildlife authority stakeholder group; the need to ensure that members of this stakeholder group were available for inclusion in the main study resulted in their exclusion as key informants (participants were not included as both key informants and main stakeholders).

Semi- Structured Interviews:

Farmer Stakeholders

To recruit farmer participants, a combination of strategies was used. Firstly purposive, convenience sampling was used to target participants. To be included in the study participants were required to farm only with livestock. For this, Cheetah Outreach Trust (COT) and AWCRC acted as gatekeepers helping to gain access to livestock farmers who were using both known and unknown mitigation strategies. The COT run a livestock guardian dog (LGD) placement programme and since 2005 have placed over 328 LGDs on farms in South Africa, primarily in the Limpopo and North West Provinces. COT places the dog at no cost to the farmer and provides all food and medical supplies during the first year when monthly monitoring and training visits are made to each participating farm. After the first year, the LGD is signed over to the farmer and visits are made less frequently. COT provided a database of all LGD placements within the Limpopo province (130 dogs). One hundred individual farmers received dogs in the Limpopo province; 35 unique farms within 100km of AWCRC received at least one LGD between 2005- 2019. The database included farmers with working dogs, deceased dogs and those where dogs had been removed. Contact with the farmers on this database was made by the researcher and it was explained to potential participants that their details had been provided by COT. The researchers' supervisor had previously conducted research projects with COT and therefore they were a trusted collaborator.

The AWCRC also provided assistance with the recruitment of livestock farmers known to the project, and provided contact details for any farmers they had previously worked with who had livestock on the farm (n=14). These farmers did not utilise a specific intervention strategy. Two farmers were both known to AWCRC and had a LGD placed by COT. The AWCRC is located on a working farm and conducts a variety of biological and social research projects. At the time of the study the majority of AWCRC's research was focused on the mitigation of baboon crop damage, camera trap surveys and community outreach. The AWCRC had not placed any livestock depredation interventions on farms in the surrounding area and as a result the local farming community did not necessarily associate carnivore-coexistence work with the centre. If asked by participants about affiliations with the project, the researcher explained that they were carrying out an independent project and were using the AWCRC as a base from which to conduct the study. Therefore, conversations and observations about livestock-carnivore interactions did not reflect on work carried out by the AWCRC and enabled the researcher to maintain some independence from the centre.

To recruit further participants, relevant local events were attended. Game and livestock auctions were held on a monthly basis in Alldays, with the exception of a period of four months from November 2019- February 2020 when an outbreak of foot and mouth disease suspended all auctions and movement of livestock. The auctions were open to the public, thereby enabling attendance by the researcher. This also provided the opportunity to build on knowledge about livestock husbandry practices in the area, which in turn helped to build rapport with farmers. The researcher was also invited to a training day at the Bosveld Boerbok Klub, which is a national organisation within South Africa for Boer Goat farmers. At the event, talks on different aspects of goat farming were attended, and to likewise present the research project to an audience of goat farmers. Attendance at local farmer union meetings helped to identify further potential participants. Some farmers were seen at multiple events therefore allowing them to become familiar with the researcher. Once identified as a livestock farmer and the potential participant engaged in conversation, the project was explained in brief and contact details exchanged. The researcher subsequently contacted the participant to arrange a meeting. Additionally, snowball sampling was utilised when participants suggested another farmer as a potential participant; these farmers were subsequently invited to participate after the original participant had arranged a meeting on the researcher's behalf. From these community-based opportunities and gatekeepers, a database of all potential participants was created (n=59).

Conservation Stakeholders

Recruitment of conservation NGOs and PAA stakeholders followed a similar process whereby key informants were firstly used to identify possible participants. To be included in the study, the participants' work had to cover the Limpopo province. Staff at AWCRC assisted with providing details of potential participants known to the project. Similarly, COT and the Primate and Predator Project (PPP) were asked to identify potential participants relevant to the study. The PPP works within the Soutpansberg Mountains and as part of their research on biodiversity conservation works with local farmers experiencing livestock loss; the project has assisted with the building of kraals and placement of LGDs. PPP and AWCRC were both established by Durham University (United Kingdom) and whilst their overall research is centred on the same themes, the two centres also conduct independent research projects in different environments (mountains and farmland). Furthermore, the Greater Mapungubwe Network is a group set up to facilitate the sharing of work on any subject, conducted in the Greater Mapungubwe Transfrontier Area, and their meetings were used to identify and meet possible participants. The meetings were held quarterly and open to all who are interested; attendance typically comprised researchers, volunteers, NGO workers, authorities, landowners, and farmers. Internet searches were utilised to identify further participants working in protected areas or for the local or national government. A database of potential participants was created, and all potential participants were then contacted by phone or email and informed about the study before inviting them to participate.

Table 2.1: Interview inclusion criteria for stakeholder groups involved in human-carnivore coexistence scenarios in Limpopo, South Africa.

Group	Definition	Involvement and Interests in Issue	Inclusion Criteria
Livestock Farmers	Farm domesticated animal species for use, profit or hobby	Farm with livestock and may interact with carnivores and/or experience depredation. May use intervention strategies to protect livestock	Farm with livestock (goat, sheep or cattle), within the study area
Conservation non-governmental organisations (NGOs)	Non-government conservation organizations working to conserve wildlife and ecosystems in South Africa	Interest in promoting wildlife conservation, work with and alongside local farming community. May place and/or recommend livestock protection intervention strategies	Work for a conservation NGO within the study area
Protected Area Authority (PAA) Staff	Employees working for national, provincial and private reserves in South Africa	Have an interest in promoting wildlife conservation, work with and alongside local farming communities. May recommend livestock protection strategies to farmers but do not directly implement them.	Work for or manage a government or private reserve within the study area
Private Tourism	Own commercial operations for tourism purposes	Interest in wildlife for tourism purposes, live alongside local farming communities	Owns land used for tourism purposes within the study area

2.2.4 Survey instruments

Key informant interviews

Key informants were engaged in a conversational interview and a question guide was used to prompt responses, where needed (Appendix 2). Confirmation of eligibility to act as a key informant was determined when the participant demonstrated knowledge of the area and livestock-carnivore interactions; at this point the interview data were considered relevant to informing the main interview study. The conversational interview was structured so as to help develop background understanding for the researcher and provide context for the study. In addition to their role in providing necessary background to inform survey design, key informants also played a role in the pre-testing of the main interview guide. Following the conversational interview, participants were asked to review a draft interview guide to be used for the main study and provide feedback on the questions (e.g., understanding, terminology and ability to respond). The findings from these discussions were used to help shape content, language and terminology for the main study interview guides. As a result of the key informant interviews, some minor changes were made to the main interview guide. For example, it was decided to use the word 'predator' rather than 'carnivore' to reflect the terminology more commonly used in the study area.

Semi-structured interviews

Drawing on observations made in the key informant discussion, an interview guide was constructed and tailored to each stakeholder group (Table 2.2). The questions were designed to explore perceptions of intervention strategy success and coexistence. Following grounded theory processes, the guide was amended and added to as the study progressed to allow for the exploration of emerging ideas and theories.

The questions acted to guide the flow of the discussion and provide prompts where necessary; they were designed to explore the following topics:

- Perceptions of and attitudes towards carnivores
- Livestock farming practises (either on the farm or used in the area)
- Use of intervention strategies / awareness of interventions used in the area
- Methods of determining intervention success
- Perceptions of coexistence.

Table 2.2: Interview guides used for main study interviews. Questions in italics represent questions added or amended to the interview guided through the grounded theory process.

Interview Guide
For Farmer Stakeholders:
How long have you been on this farm? What is the size of the property? How would you describe the main vegetation type?
Can you describe the main land uses on your property? (E.g., Livestock, game, crops, hunting, tourism, conservation)
What is the main source of income on the property?
What livestock do you farm? For each type/ species, how many individuals there are? Do you know the value of these species (Rand)?
What are the primary reasons for owning livestock? *What are the livestock used for? (E.g., profit, personal, pension fund, other). Why did you decide to farm with livestock? If you sell livestock, is it for breeding, meat, other?* *What do you think is the main reason other people in the area have livestock?*
How long have you farmed livestock?

What kinds of problems limit livestock production? Can you rank these from most problematic to least problematic? If wildlife is listed as a problem-, which species are a problem? Can you rank these from most problematic to least problematic?
Is theft or poaching a problem for you?
If yes: Has it always been a problem? Why do you think it started? How do you think it's being done? Who/ when? What losses have you had? How did you find out about them? Do you use any strategies to reduce or prevent theft? Is there anyone to report left to? Do you think your neighbours experience the same problems? For you, which is worse, losses from predators or losses from poaching/theft?
What predator species do you get on your property?
How often do you see predator species on your farm?
When was the last time predators caused a problem? Prompts: What did they do? How did you identify their presence? What happened to the predator? How did this affect you? What did the loss cost you?
How often do you think your livestock come into contact with predator species? *Is there a particular type of livestock most likely to come into contact with predators? (E.g., young/ sick).* *When do you think they are most likely to come into contact?* How many times per month do you think livestock come into contact with predators?
How often do you come into contact with predator species?
How often do you think your workers come into contact with predator species? (If relevant).
Which predator species cause the most damage on your farm?
Have you or anyone you know ever been hurt by wildlife on your farm? If yes, explain.
Are there any species you do not want to see on your farm?
Do you think any predator species are dangerous when seen on your farm?
Do you think the number of predators in this area is low, moderate, high or you're unsure?
Are the numbers of predators in the area increasing, decreasing or staying the same? Explain answer.
Do you think this trend will continue in the future?
What strategies do you use to protect your livestock?
Can you describe how you use these methods? How long have you used these methods?
Why did you choose to use this particular method?
Have you previously used any other methods? If yes, what were they? Why did you stop using them? Do you think any historic methods (E.g., use of fire/ trenches etc.) successful?
If respondent lists multiple methods; which is your preferred method? Why?
How did you find out about 'XXX' method? Did you receive help in getting it? Did any particular organisation or person influence your decision to use this method?
Would you describe this method as successful? If yes, what makes it successful? If no, what would make it successful? Why do you think it has failed? *What changes did you expect when you started using this method? Does it meet your expectations?* Would you use this method for all livestock species? Do you think this method will still be successful in a years' time? Would you be willing to try other methods in the future?
Do you participate in any collective methods with other farmers?
What other strategies can be used to protect livestock? (Can include lethal/ illegal methods). *Do you know what methods your neighbours might use to protect livestock? Are there any methods*

used in the area that might be frowned upon? Do you think people are using illegal methods? Why might they use these?
What strategy do you think would be most successful at protecting livestock? Is there anything preventing you from using this strategy? Would this method be used for all livestock species? Do you think this method would still be successful in a years' time?
How do you think the success of these methods usually measured?
Who usually determines the success of these methods?
If you could do anything to protect your livestock, what would you do?
Do you think it is possible to completely stop livestock loss and/ or injury by wildlife?
Who do you think is responsible for reducing and preventing livestock loss?
Would you like more help in protecting your livestock? If so, what?
Do you report wildlife damage to wildlife authorities? Why? Why not?
Do you think it is important for people, livestock and predators to live alongside each other?
What does the word coexistence mean to you?
Do you think that people and predator species can coexist?
What do you think is needed for coexistence to be achieved?
How would you feel if predator species disappeared from the area completely?
Game Farming: *For those that also farm game: Do you experience similar predator problems with game and livestock?* *How do people manage game (compared to livestock)?* *Do you think that game farming impacts on predator numbers?*
For Conservation Stakeholders:
Who do you work for? How long have you worked for (name of organisation)?
Can you describe your job role?
How long have you worked in this field? What did you do previously?
In which geographical area do you work/ which area do you cover?
How long have you worked in this area? Were you working in this area previously?
How would you describe the main land uses in the area?
In this area, what kinds of problems do you think limit livestock production? Can you rank these from most problematic to least problematic? If wildlife is listed as a problem-, which species are a problem? Can you rank these from most problematic to least problematic? *Do you think all farmers experience the same problems? Why?*
In general, what methods and/ or strategies do you know of that can be used to protect livestock? You can name as many as you can (this can include lethal/ illegal methods). Can you rank these methods from most successful to least successful?
Which method/ strategy do you think is most popular for farmers in the area? *Are the same strategies used for all livestock types? Are there any methods used in the area that might be frowned upon? Do you think people are using illegal methods? Why might they be using these?*
For you, what strategy do you think is most successful at protecting livestock? Would this method be successful for all livestock species? Do you think this method would still be successful in a years' time? What do you think farmers using this strategy expect?
Would you recommend using this strategy to farmers? Would you recommend it for all livestock types? If yes, have you recommended it to anyone so far? If no, why not? *What do you think is the best way to share recommendations?*
If you were a farmer and could do anything to protect your livestock, what would you do?

How do you think the success of mitigation methods are usually measured?
Who do you think usually determines the success of these methods? *Who do you think should determine the success of these methods?*
Do you think it is possible to completely stop livestock loss and/ or injury by wildlife?
Do you think there is a livestock species that is easiest to manage or protect?
Who do you think is responsible for reducing and preventing livestock loss?
If a farmer experiences loss, is there anyone they can report it to? *What do you think farmers in this area are most likely to do if they experience losses?*
If wildlife damage is reported to you, what do you do? If you hear about illegal/ lethal methods being used is there anything that you can do?
Game Farming: Do you think game and livestock farmers experience similar problems? How do people manage game (compared to livestock)? Do you think that game farming impacts on predator numbers?
Do you think theft or poaching is a problem in the area? If yes, other prompts: Has it always been a problem? Why do you think it started? How do you think it's being done? Who/ when? Do you think people use any strategies to reduce or prevent theft? Is there anyone to report left to? Do you think all farmers experience theft/ poaching? Which do you think may cause bigger losses theft or predators?
In general, what predator species do you have in this area?
How often do you see predator species in your work? (If relevant) How often do you think farmers actually see predators? How often do you think they might see spoor? How often do think livestock come into contact with predator species? How many times per month do you think livestock come into contact with predators?
Which predator species do you think cause the most damage on farms in the area? Which species do farmers think cause the most damage?
Do you think any predator species are dangerous when seen on farms?
Do you think the number of predators in this area is low, moderate, high or you're unsure?
Are the numbers of predators in the area increasing, decreasing or staying the same? Explain answer.
Do you think this trend will continue in the future?
How do you think farmers are estimating predator numbers on their property?
Do you think it is important for people, livestock and predators to live alongside each other?
What does the word coexistence mean to you?
Do you think that people and predator species can coexist?
Do you think that livestock farmers and predators can coexist?
What do you think is needed for coexistence to be achieved?
How would you feel if predator species disappeared from the area completely?

2.2.5 Survey administration

Key Informants

Conversational pilot interviews were conducted between July - August 2019 with three participants who identified themselves as being from either the farmer (n=1) or NGO stakeholder group (n=2). Conversational interviews and interview pre-testing were conducted at a location convenient to the participant. All conversations were conducted in English and recorded using a Dictaphone (Speak-IT Premier Digital Voice Recorder).

Semi- structured interviews

Interviews for the main study were conducted between September 2019 and May 2020. In the farmer stakeholder group, 37 potential participants were contacted via phone to invite them to interview. The majority (n=20) responded positively, and interviews were subsequently arranged. Of the remaining 17, five responded with reasons to be excluded from the study including relocation outside of the area (n=2), cessation of farming (n=2) and being unwilling to participate for undisclosed reasons (n=1). Participants who failed to respond to three messages and/or calls were excluded from the study (n=12). For the farmer interviews, only those within 100km of the research base were contacted as this distance was deemed feasible for daily travel (road conditions often increase travel time beyond typical commuting times).

Interviews were conducted with the person on the farm who identified themselves as having the most knowledge about the livestock. In most cases this was the farm owner (n=19), although on one occasion it was a farm manager. Interviews were conducted at a location chosen by the participant; 19 interviews were conducted on the participant's property (either at the house or farm office), and one interview was conducted at an auction kraal where the participant was working. It was observed that the participant's partner would frequently listen to the interview from a nearby room and would occasionally make comments in response to questions. These comments were included in transcription and identified as being made by someone other than the main participant.

In the NGO and PAA stakeholder groups, 28 potential participants were identified and contacted via phone to invite them to interview. Thirteen did not respond and four gave reason not to be included in the study e.g., no longer working in the area (n=3) or retired (n=1). Eleven responded positively and interviews were arranged. Six interviews were conducted in person at a location chosen by the participant. Due to restrictions imposed by the COVID-19 global pandemic (beginning March 2020 and continuing beyond the study end in December 2020), five interviews were conducted remotely online using MS Teams or Skype (the platform was determined according to participant preference). If possible, separate interviews were conducted with multiple people working for the same organisation (n=6 from 3 organisations).

All interviews were conducted in English. If a participant did not know the English translation for a word or term, participants would ask other household members or colleagues to translate specific words from Afrikaans to English to assist them. During subsequent transcription a native Afrikaans speaker confirmed the accuracy of these translations. In-person interviews were recorded using a Dictaphone whilst NGO interviews conducted remotely were recorded using MS Teams recording function or Skype recording. After each interview, the researcher's thoughts and observations on the interviews were recorded as field notes, as well as relevant details of conversations prior and post interview. Field notes were written as soon as possible after each interview, either before leaving or as soon as back at the base. Participants were thanked for their time, but no payment or reward was made for the participants' time.

2.2.6 Participant observation

Participant observation was initiated at the start of the study in July 2019 and continued for the full duration of in situ fieldwork (July 2019- March 2020). Observations encompassed anyone, regardless of stakeholder group, who was opportunistically observed to interact with the study area during this period. Observations made during the key informant interview phase were used in the refinement of the language used in the main interview guides by ensuring that only locally relevant terms were used, as well as helping to identify any additional questions that needed to be addressed. Some farmer participants chose to accompany the researcher on trips around their property for the purpose of camera trap maintenance (See chapter 4.2.2); this time together in the car often resulted in insightful conversations and provided the opportunity to talk away from an interview setting, which may have been regarded by participants as more formal. A field notebook was kept to write down any observations or conversations as soon as possible after these interactions in the form of field notes.

To build relationships with both farmer and conservation stakeholders a variety of local events were participated in. Attendance at these meetings and events helped the researcher to engage with all stakeholders and gain a more in-depth understanding of the issues and challenges faced by the different stakeholders. In addition to these more formal meetings, the researcher was invited to attend social events such as braais (BBQ) and birthday parties primarily with farmer stakeholders which gave an insight into their daily lives. Local restaurants were visited which provided opportunities to talk further with farmers already participating in the study as well as connect with others. Overall, more time was spent with farmer stakeholders; conservationists (outside of those at AWCRC) were often met only at pre-organised events. Whilst recognition of the researcher amongst the conservation community occurred due to collaboration with multiple organisations, these relationships were arguably more formal and primarily work focused. Through this active engagement with the community, it was possible to conduct participant observation in a variety of settings and become recognised locally by both farmers and conservationists. Over time, it is thought that this recognition developed trust and helped to result in more honest and open conversations. By not limiting conversations and interactions to interviews, participant observation helped to triangulate data and provided the opportunity to test the accuracy and validity of interview data through further conversations and observations of behaviour.

2.2.7 Data analysis

All interviews were conducted and analysed using a grounded theory approach. Prior to analysis, all interviews were transcribed using semantic style transcription, adapted from Jeffersonian transcription protocols (Jefferson, 2004). All spoken words were included as well as details such as false starts, laughs and repetition. Pauses were indicated but not timed. During transcription of the key informant interviews, a transcription protocol was developed for the main study to allow for consistency in transcription and to reduce the chance of transcriber fatigue. This protocol is included as Appendix 3 for the sake of transparency and repeatability as per Young *et al.,* (2018). The protocol listed what to include in transcriptions, formatting and use of symbols. As far as possible, transcription was conducted as soon after the interview as feasible (range: 1 - 90 days).

Transcripts were then coded following Charmaz (2006) using initial, focused and theoretical coding. QSR NVivo v12 (http://www.qsrinternational.com) qualitative analysis software was used to record the codes. Initial coding occurred line by line using gerunds to draw out the participants' actions. The initial coding generated substantive codes from the data, developing theory, directing where to go next and further questions to ask in subsequent interviews. Initial coding was followed by focused coding. During focused coding the most frequent or significant initial codes were identified. The theoretical direction of the coding was advanced through codes becoming more conceptual than line by line and tentative decisions were made about which initial codes made the most analytical sense. Theoretical coding was then used to help theorise the focused codes and identify relationships between the categories identified in focused coding. This process led to the formation of the overall analytical story.

Following the initial coding of eight farmer interviews, ideas and theories began to emerge. The emerging themes were then reviewed, and it was decided which needed further exploration or were of greater interest to the project. Once these themes for further investigation were identified, the original interview guide was reviewed and amended. This determined the direction of future investigation and further questions that needed to be asked of participants. Using theoretical sampling, additional farmer participants were then selected, and subsequent interviews conducted to explore ideas that were emerging from the data.

Prior to conducting any interviews with conservation stakeholders, the interview guide was adapted to explore any emerging theory or hypothesis from farmer interviews which were also relevant to, or worth exploring with conservation stakeholders. After conducting six interviews with conservationists, responses were then used to guide further farmer interviews (n=5). In this way, responses were used to inform future interviews with different stakeholders to ensure that all emerging theories were explored with all stakeholder groups. This process of moving between data collection and analysis occurred throughout the study. Throughout the coding process memos were kept to document reflections and thinking. Memos were used in the back-and-forth process between analysis, data collection and coding. Memos were used to define codes and theories, explore relationships between codes and make comparisons across the dataset.

In grounded theory, there is no required or standard sample size for conducting semi-structured interviews. Consequently, the study did not set out to conduct a fixed number of interviews; rather the aim was to reach theoretical saturation, i.e., the point when continued data collection fails to reveal or add any new information (Newing, 2011). After conducting a number of interviews, it became possible to predict how a participant was likely to respond to particular questions based on their responses to other questions and the responses provided by previous participants of similar backgrounds. Theoretical saturation was considered to have been achieved when this predictive ability occurred in >3 consecutive interviews within each stakeholder group.

Participant Observation

All field notes were digitised for analysis and entered into qualitative data analysis software (QSR) NVivo v12. Field notes were coded as above using initial, focused and theoretical codes to draw out concepts and theories from the observations. Analytical memos were kept to document thoughts and ideas throughout the coding process.

2.3 Results and Discussion

Thirty-one interviews were conducted in total: 20 farmers, 7 NGO workers, 3 PAA and 1 private tourism/conservation operator. Interviews lasted between 20 minutes and 1 hour 43 minutes with an average length of 45 minutes, depending on participant engagement. On some occasions (n=2), the participant had a restricted timeframe of availability; in these instances, the interview was conducted within this timeframe and responses may therefore have been briefer than for unrestricted interviews. All interviews were conducted in one visit or conversation. Participant observation and informal conversations continued during unplanned meetings within the community, e.g., at social events or areas.

Participants ranged in age from 27 to 81, with an average age of 50.5 years. Of the participants, 27 were male and four were female. Of the farming group, participants were predominantly male (18 M, 2F; Table 2.3). The majority of conservation stakeholders were also male (9M, 2F; Table 2.4). All PAA participants were male. As the study progressed, it became apparent that farming businesses were operated in partnership between husband and wife with it being commonplace for the wife to manage visitor access to the property. It is essential that interviewers observe and take on board local customs and social taboos to help participants relax and accept the project (Newing, 2011; Young *et al.,* 2018). Therefore, in order acknowledge and adhere to local etiquette, it was often important to include wives in making interview arrangements so that they were accepting of, and comfortable with, the project occurring on the farm. As a female researcher, this was particularly important to prevent the interview being regarded with any suspicion. Nine farmers had a higher education qualification. All NGO and PAA stakeholders had a higher education qualification. Farmers in the study kept sheep, goats and cattle, all of which are vulnerable to carnivore depredation.

Quotes are used throughout the text with participant ID provided after each quote; the prefix "F" is used to represent farmers and "N" represents conservation stakeholders. It should be noted that classification in this way was based solely on the participants occupation, not their values or beliefs.

Table 2.3: Demographic information and participant profiles for farmer stakeholders

Gender	Age	Education	Position on property	Farm boundary type	Farm Size (Ha)	Land Uses	Primary Source of Income	Livestock	Intervention Strategy
Male	81	Diploma	Owner	Game, some cattle	3000	Cattle, Game	Cattle	Cattle	None
Female	40	Diploma	Co-Owner, Manager	Game Fence	2x 800	Game, Livestock, Hunting	Cattle, Game	Cattle, sheep	Electric fence kraal, near to house, previously LGD
Male	39	Diploma	Co-Owner, Manager	Game Fence	2400	Game, Hunting, Cattle	Hunting	Cattle	Kraal (only for pregnant), near to house
Male	70	Secondary	Owner	2 sides game, 2 sides cattle	856	Cattle	Cattle	Cattle	Cage Trap (after loss)
Male	44		Owner	Game Fence	428	Crops, Cattle	Crops	Cattle	Kraal
Male	68	Diploma	Owner	Game Fence	286?	Livestock	Livestock	Goats, sheep, cattle	Kraal, 3x LGD, near to house
Male	60	Secondary	Owner	2 sides game, 2 sides cattle	1760	Cattle	Cattle	Cattle	None
Male	57	Secondary	Owner	Game fence	7000	Livestock, Hunting	Livestock, Hunting	Oxen over 275kg	Started speculating (as a result of loss to carnivores)
Male	46	Secondary	Owner	Game fence	1851	Crops, Livestock, Game	Crops	Goats, cattle, sheep	Kraal, 5x LGD, some kraal=electric, herder with goats
Male	37	Secondary	Co-Owner, sales manager	Electric game fence	900	Crops, Game, Hunting, Livestock	Crops	Cattle, sheep	Electric fence camp, cage trap
Male	54	University	Owner	Game fence, partly electrified	3000	Game, Hunting, Crops, Livestock	Crops, Hunting	Cattle, sheep	Electric fence camp, close to house
Male	76	Secondary	Owner	Game Fence	824	Crops, Livestock	Crops	Goats, sheep, cattle	Herder, LGD with goats, kraal
Female	46	Diploma	Co-Owner, Manager	Game Fence	1500	Crops, Game, Hunting, Livestock, Tourism	Crops	Sheep	LGD, electric fence, herder, herder lives next to kraal, lights
Male	35	Secondary	Co-owner, Manager	Game fence	1700	Game, Livestock, Hunting, Tourism	Hunting	Goats	LGD, electric fence kraal, herder
Male	27	University	Manger	3m electric game fence	4600	Crops, Game, Hunting, Livestock	Crops	Goats, sheep	Gun, electric fence camp
Male	34	University	Co-Owner	Game Fence	6400	Game, Game feed	None	Few cattle (Sold)	
Male	67	Secondary	Owner	Game fence	2100	Livestock, Game	Livestock	Goats, Cattle	Goats=kraal, LGD, cattle= nothing
Male	72	Secondary	Co-owner	75% game fence, 25% cattle	1400	Cattle, Game	Cattle	Cattle	None
Male	50	University	Owner	Game fence	600 (+2500)	Crops, Livestock, Game	Crops	Sheep	Kraal (inside electric crop field), herder
Male	55	Diploma	Owner	Game Fence	3600	Cattle, Game, Crops	Crops, Cattle	Cattle	LGD, kraal young calves

Table 2.4: Participant profiles for NGO and protected area stakeholders

Gender	Age	Education	Organisation	Classification
Male	33	University	Private Reserve	Manager
Male	50	University	Government Reserve	Manager
Female	31	University	Wildlife Conservation NGO	Research Coordinator
Male	27	Diploma	Wildlife Conservation NGO	Research Coordinator
Male	66	University	Private Conservation Lodge	Owner
Male	50	University	Government Reserve	Manager
Female		University	Wildlife Conservation NGO	Research Coordinator
Male		University	Wildlife Conservation NGO	Research Coordinator
Male		University	Wildlife Conservation NGO	Project Manager
Male	50	University	Wildlife Conservation NGO	Project Manager
Male		University	Wildlife Conservation NGO	Project Manager

2.3.1 Perceptions of and attitudes towards carnivores

Carnivore sightings

Black backed jackal were reported by all stakeholders as the most frequently seen carnivore species with five (of 20) farmers seeing them on a daily or weekly basis. Other species such as leopard and cheetah were rarely seen by farmers and conservationists.

“I’ve seen leopard in 25 years two times.” F05

“In the 12 years that I’ve been working for XXX I’ve never see a leopard or a cheetah in the wild.” N11

Carnivore behaviour emerged as a factor in why farmers thought sightings were infrequent. Leopards were described as being shy and skittish around humans and considered to usually run away before being seen.

“Mostly if you see a leopard they will walk, will go away.” F02

“They’ll normally avoid you, you know if there’s a leopard if he sees you and even the cheetahs, they will run away.” F08

Additionally, it was reported that large carnivores were rarely seen due to being predominantly nocturnal and therefore moving around the farm when the farmers were not active.

“So you’ll see frequently you’ll see tracks but they’re very skittish and they move at night, then I sleep.” F10

“Then the leopards is sleeping in the day you know how they hunt in the night.” F06

“And at night you’re in the house so the most you see of them is the tracks the next day.” F07

The emergence of these factors demonstrates farmers have some knowledge of carnivore behaviour. It is widely recognised that knowledge about carnivores can affect people's attitude, tolerance and willingness to conserve a species and therefore it is important to explore how carnivore behaviour is understood (Bennett *et al.,* 2017; Mkonyi *et al.,* 2017; Bickley *et al.,* 2019). It has been suggested that people's understanding of behaviour can help foster coexistence, with more knowledge about a species being associated with a greater likelihood of the species being viewed positively (Dorresteijn *et al.,* 2016; Bickley *et al.,* 2019). Schumann, Walls and Harley (2012) found that farmers who understood the ecological role of carnivores were more positive and less likely to want all carnivores removed from the area. To date, local knowledge about species behaviour has primarily been collected through interviews and questionnaires. Madsen *et al.,* (2020) argues that local ecological knowledge (LEK) has been underused as a source of behaviour knowledge about species involved in negative interactions. LEK is the environmental knowledge held by people that live in close contact with wildlife and obtain their knowledge through interactions with the local environment (Brook and McLachlan, 2008). The use of LEK to understand carnivore behaviour in HCC scenarios could help to reveal behaviours that are considered desirable and undesirable to farmers, therefore highlighting areas that need addressing in HCC interventions. Reports of carnivore behaviour may not only assist in understanding the factors that shape farmer attitudes and behaviours towards carnivores but provide information to conservationists on how carnivore species may respond to living in human dominated areas.

Animal avoidance of an area can be regarded as a response to living in a human dominated landscape of fear (Goswami *et al.,* 2014), and it has been found that carnivores in anthropogenic environments can adjust their spatial movements and activity patterns to avoid potentially fatal contact (Loveridge, Kuiper, *et al.,* 2017; Ramesh *et al.,* 2017). However, not all carnivores respond to human activity in the same way, and some may prefer human occupied areas to avoid inter-specific competition and gain increased access to water sources (van der Weyde, Mbisana and Klein, 2018). This behaviour may be reflected in farmer's perceptions that their farming practices and borehole use encourage carnivore species onto their property. These carnivore behavioural adaptations may mean that farmers are more likely to see signs or damage caused by carnivore species rather than the actual animals themselves which could contribute to a feeling of lack of control.

"Especially the brown hyena, jackal, caracal we don't see but we see the damages." F16

"They don't see them that often, they see the, you know they see the consequences of the leopard." N08

Despite not seeing carnivore species, six farmers reported seeing spoor on a daily basis. Regular sightings of spoor can make it easy for farmers to blame carnivores for problems. Those that now work on the same property on which they grew up (n=4) reported seeing more spoor now than when growing up. Frequency of spoor sightings also contributed to the perception that carnivore numbers are increasing. However, spoor does not directly measure carnivore numbers and increasing spoor sightings could be explained by better access for farmers through the farms (e.g., more farm roads), driving through the farm more frequently and/or better knowledge about spoor.

"Here's a thing, that's also another thing what I can say that we've got way many more predators than we ever had when I was growing up as a kid [on the same farm] if you saw a leopard track or if you saw a hyena track you told everybody it was a big thing, the neighbours would come and see how the tracks look like, you just never, you just maybe once a month you just saw one by chance. I can take you every single morning now, at least one or two leopard tracks or at least 3, 4 hyena tracks, every single morning I would be able to show you on this place if I go looking." F03

NGO participants suggested that farmers were likely to blame leopard and hyena for depredation as their spoor is easiest to identify. However, the presence of spoor near the site of a dead livestock animal does not necessarily indicate cause of livestock death and NGO participants expressed concern that some farmers may not acknowledge this.

"They would probably say leopard and your brown hyena [that would do the most damage]. That's often the species that are easiest to identify via spoor. They move a lot so you can find the spoor everywhere on the properties so often inflate the numbers it easy to think about, erm and especially with your hyenas since they're kind of your last animal that often gets to carcasses they are always to blame as the one that killed it erm because their spoor is the most fresh around the carcass." N04

This interpretation of spoor may also be regarded as an example of illusory correlation whereby participants assumed a correlation between seeing more spoor and subsequently blaming carnivores for livestock loss. Illusory correlation occurs when a relationship is assumed between two variables that in reality are not correlated (Chapman, 1967). Illusory correlation studies demonstrate that people can make inaccurate inferences about the relationship between two events and often fail to acknowledge the role of other factors (Hamilton and Gifford, 1976). Stereotypes can result from illusory correlation as was demonstrated here with some farmers creating stereotypes about carnivore behaviour from the presence of their spoor.

It should be noted that unlike previous studies, the current study did not measure participants' ability to correctly identify carnivore species or their spoor (Cavalcanti *et al.,* 2010; Mkonyi *et al.,* 2017; Fort *et al.,* 2018). Lack of ability to successfully identify carnivore tracks has been noted in previous studies (Rutina *et al.,* 2017), and misinterpretation may contribute to the perception that carnivore presence has increased. However, other studies have confirmed the accuracy of LEK and ID skills (e.g., Rutina *et al.,* 2017). The use of LEK to gain conservation information is growing with recent studies (e.g., Madsen *et al.,* 2020; Camino *et al.,* 2020) showing that LEK data can be a reliable method for assessing species presence and habitat preference. Therefore, engaging with farmers to obtain LEK will not only provide insight into species and spoor ID skills but also reveal information about perceived wildlife behaviour and/or presence, helping to reveal knowledge that contributes to local perceptions of carnivores.

Carnivore species were not generally perceived as dangerous by any stakeholders unless given a reason to attack such as being caught in a cage, caught in a snare or wounded from hunting.

"They won't just attack, they would, you would have to give them a reason to attack then they're dangerous but otherwise no." F10

"Unless you've caught them in a trap or a snare or a gin-trap then they become dangerous but no they're not dangerous at all." N09

Five farmers and one PAA reported hearing of people being hurt by leopards, with one farmer reporting a family member being attacked by a leopard. Nonetheless, the majority of interactions between people and carnivores were thought to occur infrequently with no serious consequences to people. Despite farmers expressing that carnivores were not dangerous, one PAA felt that some landowners have a mentality that if "a predators got teeth it's going to hurt you" (N01) and pass this attitude onto their children who can then become fearful of carnivore species. However, some farmers considered other wildlife found on the farms such as snakes and buffalo more dangerous than carnivores typically involved in livestock depredation (e.g., felids).

"Most dangerous thing I think actually now is the black mamba." F02

"I face a leopard but the mamba uh uh." F17

"I think though that the most dangerous thing on this farm is the buffalo. I'd rather walk into a leopard than walk into the buffalo on foot." F14

The opinions expressed here by farmers for preferences of other species over carnivores reveals a probability discounting bias (Baker *et al.,* 1993), where the risks associated with leopards are moderated through comparisons with other species that are deemed riskier.

Perceived population size

Participants were asked whether they thought carnivore populations were low, medium, high or if they were unsure. The majority of farmers (n=14) thought that carnivore numbers were high and increasing; in comparison only one conservationist (of 11) reported numbers as 'high' with five classifying populations as medium. Reasons why farmers reported a perceived increase in carnivore populations emerged in three main categories; Table 2.5 presents the initial and focused codes that make up the category. Similar perceptions were found in a study of livestock farmers in the Karoo who also reported perceived increases in caracal and baboon populations (Drouilly *et al.,* 2018).

Table 2.5: The initial and focused codes that made up the category of farmers perceiving an increase in carnivore populations.

Category	Focused Codes	Initial Codes
Carnivores Increasing in Number	Farming Practices	Dehorning of cattle Increasing boreholes Carnivores using fences to hunt Availability of easy meals
	Changes in Environment	Increasing game farms Increasing weekend/unoccupied farms Drought increasing carrion Increasing accessibility (more farm roads/better transport)
	Economics	Removal of hunting permits Lacking support from authorities Increasing labour costs (fewer herders) Decreasing technology costs e.g., camera traps available for personal use

Farmers reported that carnivores were able to use fences to facilitate successful hunts; this aligns with empirical studies demonstrating that wild dogs are able to use fences to increase hunting success (Davies-Mostert, Mills and Macdonald, 2013). Additionally, whilst boreholes assisted with livestock rotation and drought resilience, it was suggested that permanent water features attract some carnivore species and enable them to live in areas that they would otherwise be unable to occupy for extended periods, as occurred in the Karoo (Archer, 2000). The development of technology and equipment to aid agricultural production was therefore considered by farmers to contribute to the perceived increase in carnivore numbers. Increased carnivore numbers were also attributed to an increase in game and hobby farms within the area; increased sheep predation has been considered as a consequence of a rise in 'lifestyle' farmers who have little interest in making a living solely from farming (Reed and Kleynhans, 2009), and may therefore invest less (if anything) in predator control.

"I would say one of the main, one of the big things is there is, there's a lot of er farms and stuff in the area, properties that's unoccupied, they all have livestock and game and this and that but the guy stays somewhere else and they're not here anymore. Remember years ago, every single farm out here had cattle or goats or some form of livestock on it and whenever anybody figured out let's say listen but here's a calf missing, here's a lamb missing or something, they'll go find out what it is and a lot of times they just poison it so whatever was catching the stuff, everybody tried to eradicate them and now it doesn't happen." F03

"I think there's more predators now than 20- 30 years ago with all this game farms and farms that people don't live on and so I think the population is more because 30 years when we were farming here you couldn't see any tracks of the leopard or something like that and now it's easily you see something every week or so." F09

"It is because of the game fencing, the game farmers some of the people is not staying on the farm, they just have the farm, it's not like in the old days with the cattle farmers if they saw a track of a predator they will make a plan to get rid of it, nowadays the predators have a much better chance of making it." F16

No farmer participants thought that carnivore populations were decreasing, but in contrast to this three NGO and PAA participants indicated a concern that carnivore populations were decreasing and only two suggested that populations were slowly increasing. The primary causes of perceived decrease were considered to be habitat fragmentation, illegal hunting and increasing human populations.

"It's the illegal hunting and poaching of them, because poaching often is not very targeted towards species although they want to go more for herbivores they don't always do. The illegal hunting has a high impact in this area on species. And then also habitat fragmentation actually due to the fences for game farming that's causing major problems for your predators, so their numbers are dropping, from those three." N04

Carnivore densities were thought to be lower on farmlands than in large protected areas with PAA's describing their reserves as safe harbours for carnivores. Participants were not directly asked about carnivore density, however, six (of 20) farmers felt that leopard were likely to be found in certain areas of their property such as mountains or koppies (rocky outcrops), showing that carnivores were considered more likely to inhabit more remote areas of farmland. The views expressed by NGO and PAA participants reflect the results from previous camera trap and collar surveys conducted in the

Soutpansberg Mountains which show an extremely rapid decline in the density of leopards between 2008 and 2016 (Williams *et al.,* 2017). Three NGOs suggested that, in contrast to their opinions, farmers thought populations were increasing. Whilst this shows an awareness from NGO workers that they may differ in opinion to farmers, the opposing beliefs reveal contrasting perspectives between stakeholder groups with the potential to have significant consequences for the support of conservation initiatives. On the contrary, one NGO participant thought farmers shared their opinion that leopard populations were decreasing as farmers had reported to the NGO that leopards were seen less frequently than historically. This report to the NGO contrasts with the perceptions expressed by farmer participants themselves in this study and subsequently may reflect a misperception held by the NGO of the general opinions of the farming community. Whilst the report to the NGO worker may accurately reflect the opinions of some farmers (not represented in this study), it may also demonstrate that some farmers may report to NGO staff what they think the NGO want to hear, or that farmers who are more positive about carnivores are more likely to interact with the NGO community. This highlights the importance of obtaining the perspectives of all stakeholders involved in HCC scenarios. Differences in opinions between conservationists and other stakeholders should not be overlooked because such differences can hinder support for conservation, increase conservation opposition and result in local resistance to projects (Frank, Glikman, and Marchini, 2019).

Eradication not thought possible

There was a strong belief amongst farmer participants that carnivore species will never become extinct in South Africa as farmers have been trying to eradicate them since the first domestic cattle farms were established but have yet to succeed in all places. Jackal and caracal have been widely persecuted in South Africa for over 300 years and populations continue to survive.

“There’s no way you can kill all of them in this bushes, no way, look at the farmers in the Kalahari for generations they try to finish the jackals…And this is going on for decades there’s no way you will finish them because there’s too much hiding place for them.” F07

Studies having shown that killing is counter-productive and these species respond to persecution through compensatory immigration and reproduction (Kerley, Wilson and Balfour, 2018; Nattrass and Conradie, 2018). However, the belief that lethal control will not lead to extinction also provides farmers with a reason for not using non-lethal intervention methods and continuing with historical methods. This view, together with a perception that populations are increasing, may provide justification for conducting lethal control and a belief that it is not necessary to take measures to conserve carnivore species.

Cheetah were named as the species NGO and PAA participants were most concerned about becoming extinct in South Africa. However, localised extinctions of wild dog and lion were thought to be most likely to occur in the study area. Lions have been found to be especially vulnerable to persecution and are often the first to be eradicated from areas (Oriol-Cotterill *et al.,* 2015). Leopard were thought to be most resilient to human presence as they are known to survive even in cities.

"I don't think we'll ever totally exterminate, well maybe certain species, certain species are, are hated more than others- wild dog and cheetah in particular are disliked in your area, funnily enough leopards which are actually probably some of the biggest culprits they seem to be tolerated more by farmers which is very, very strange- not by everyone, only certain farmers that, that kill any predator on sight, anything with teeth, shouldn't be in that area in their opinion but there's nothing you can do to change those kind of farmers perceptions." N09

The NGO worker here highlights that it may not be possible to change the perceptions of all farmers which could form a major barrier to achieving coexistence. There is an urgent need to explore this further to understand why these perceptions may be held and whether it is possible for conservationists to work with these farmers in order to achieve their goals.

Livestock-carnivore interactions

Participants were asked to estimate the frequency of interactions between livestock and carnivores. Interactions were not limited to those that resulted in livestock fatalities and included any occasions in which the two types of animals may be in the same place at the same time. Livestock were most likely to interact with jackal, with some farmers reporting daily interactions.

"Ah at least, oh well must be about, it must be about every night." F03

Interactions with larger species such as leopard were thought to be infrequent; occurring on a monthly or rarer basis.

"Well jackal regularly because it's quite a lots of them here and er I think this brown hyena's maybe also lots of times cause their spoors is always in the road. The bigger ones, leopard and those type of things very rarely I would say." F18

There was a high variation in responses and not all participants (n=7) wanted to estimate interactions as they felt unable to answer accurately; NGO and PAA participants were less likely to estimate in comparison to farmers. A major reason for NGO and PAAs participants feeling unable to answer was that interactions were most likely to occur at night so were rarely seen or recorded. Participants confirmed interactions through the presence of spoor or livestock depredation. However, it was thought that the majority of interactions did not result in livestock fatality. Other signs of interactions were changes in livestock behaviour including cattle standing rather than lying, signs of running inside of the kraal and damages to kraal fences. It was reported that interactions were most likely to take place at water sources or at a kraal whereby livestock would be inside with carnivores passing on the outside. Fatal interactions were most likely to occur at night; similarly, Kissui (2008) found hyena and leopard were most likely to attack at night and Lichtenfeld, Trout and Kisimir (2015) reported that predation caused by hyena, lion, leopard and jackal occurred at night with only one jackal attack occurring during the day. The amount of livestock loss attributed to carnivore depredation varied per farm.

"A month ago a leopard caught one of my dad's calves and then two weeks before that a brown hyena caught also a calf." F10

"Very limited problems, not much, maybe the last five years I've lost two animals maybe." F19

If interactions ended fatally, participants were asked about how they determined cause of loss; farmers used spoor and location of injury to determine cause of death. However, it was acknowledged that loss could be caused by other reasons such as disease or theft.

"*Ja, you can see if it's on the neck you can be sure it's leopard, if it's bitten from behind it's hyenas*." F07

"*And er the calves because we go and see them everyday or every other day we saw the tracks one was a brown hyena and the other one was a leopard."* F10

"*And ja, and then you won't even know because the calves is in the veld, with the mothers sometimes you see the cows lost a calf but you don't know if it's a predator or if it died of some sickness you know, so but no the, the, the stealing is the biggest problem by far."* F18

Young livestock were reported to be the most vulnerable to loss.

"As soon as it's calving season then we start getting problems so it's when they're in calving season when's there's young ones it's a weekly thing but if you can look after that, the calves when they're like weaned then you don't have a problem." F10

"If, if there's the small lambs er the, the chance for rooikat (caracal) to chase them or to eat them it's very high, is high." Partner of F06

Perceptions of damage

Leopard were most frequently reported by farmers as causing the most damage on farms (n=15/20). Other species thought to cause the most damage were: brown hyena, spotted hyena, jackal, baboon, caracal, elephant and people. Two farmers named snares, as opposed to wildlife, as causing the most damage on their property. The majority of NGO and PAA participants anticipated that farmers would blame leopard for causing the most damage (n=8/11). However, when asked which species NGO and PAA participants personally thought most likely to cause the most damage, a number of species were named including leopard, spotted hyena, brown hyena, jackal, caracal and lion. Jackal were named as mostly likely to cause damage to small stock (n=2). The varied responses highlight that negative interactions can occur with all wildlife species and are farm specific. The responses reflect the multi-functional landscape of the study site in which multiple human activities (livestock-, crop-, and game-farming as well as hunting), interact with multiple species of wildlife. Risk of depredation is likely to be higher in landscapes where multiple carnivores occur as livestock owners may experience concurrent losses by different species (Chaka *et al.,* 2021). Carnivores have been found to show preferences in livestock predation with some species (e.g., leopard) targeting large livestock and others, such as jackal, focusing on neonates; in landscapes with multiple carnivores species livestock may hence be at risk year-round (Chaka *et al.,* 2021). Despite this, the majority of research on HCC tends to focus on single species which can over-simplify complex systems of human-wildlife interactions (Pozo *et al.,* 2021). On all study farms, human and farming activities overlapped with multiple wildlife species and the impacts of these different interactions (livestock loss, crop damage and property damage), contributed to farmers' overall perceptions of carnivores.

Fewer species were named by NGO and PAA stakeholders as damage-causers, which could reflect their focus on HCC and suggest their perceptions are orientated towards their work and not influenced by other potential wildlife issues which may occur simultaneously. Similarly to Pozo *et al.,* (2020), the majority of species were only associated with one type of damage in the current study, either livestock loss or crop damage; baboons were the only species reported to cause damage to both livestock and crops. Of the farmers (n=9) that experienced both livestock loss and crop damage three felt that damage caused by baboons and elephants were more costly and harder to manage. Those that farmed both crops and livestock were also more positive about the presence of jackal due to their role in controlling rodent populations.

"*The main thing that we got problems with is on the irrigation, that is nothing to do with my livestock, is elephants. Ja, they come in the night and they destroy everything, my electric fences and everything. At the moment they finished about 4 hectares of Lucerne. Phwit. Gone. They finished it completely."* F12

2.3.2 Livestock farming practices

Limitations to livestock production

Four main limitations to livestock production were identified by farmers: drought, disease, predation and theft. This is similar to other studies conducted in South Africa which identified all of these with the exception of disease as being faced by commercial small livestock producers (Stannard, 2003; de Waal and Avenant, 2008). Losses from disease or theft can exceed losses caused by carnivores, however it is predation that may elicit retaliatory killings and has significant conservation consequences (Ogada, M.O., 2015; Gebresenbet *et al.,* 2017). Social factors, including cultural norms and opposition to conservation, can be more important in driving retaliatory killings than wildlife damage incurred (Dickman, 2010; Dickman and Hazzah, 2015). Therefore, it is important to explore and understand all factors that may motivate wildlife killings (Inskip *et al.,* 2014). Overgrazing and management were listed as limitations to production by conservationists but not by farmers. Lack of government support, including the removal of leopard hunting permits, was also reported as limiting production by farmers. Farmers did not consider their own actions or management as limiting factors which may demonstrate a preference to blame external factors rather than accepting that their own behaviours can limit productivity. Of the limitations listed by farmers, carnivores may become the focus of farmers' frustrations as they were the main factor in the immediate environment that they can still have agency over. Subsequently, the use of lethal control can be justified on the basis of feeling unfairly treated in other ways. This can be regarded as an example of attribution theory which is the process individuals use to explain the causes of their behaviour (Heider, 1958). Attribution theory recognises that humans have a preference to blame external factors when things go wrong and it is one's circumstances, rather than personal choices, that provide justification for a behaviour.

Fighting for survival emerged as a theme amongst farmer participants who expressed that it was hard for farmers to make a living as they battle with so many elements.

"This is my survival, I'm fighting drought, I'm fighting diseases, I can't fight them (predators) too." F07

"At this stage of the fight farmers are really struggling with drought, with the government, with the strikes, with everything, with the economy, that you can't struggle with losing money due to predators so you and that's why I say you go to extreme measurements now to get rid of them." F10

The use of such words and phrases reveals underlying causes of contention, particularly in regard to lack of support from local authorities and the government as a whole.

"I want a permit for a leopard and they said ok erm I must bring them proof so that year I lost 5 calves, I bring them photos and GPS points where the leopard catch them they said ok no sorry they can't give

me a permit so I shot 5 leopards …I take in the pictures and say here's your 5 leopards you won't want to give me a permit for, they freaked out, I said give me a permit, if I get, if I shot one I get 40, 000 bucks for a leopard that cover at least 4 or 5 calves then I won't fight them. But what happened now the price has gone because they don't want to give permits so now you just you kill it." F20

Conducting lethal control of carnivores could therefore be seen as an act of frustration and is the visible outcome of contention between farmers and the government. Arguably, contention has risen out of changes to historical practises which farmers expressed as leaving them feeling neglected and frustrated. It was reported that historically farmers could seek support from local wildlife authorities to assist with problem animals, whereby the authorities would set cage traps to relocate problem animals. However, it was reported that this no longer occurs, with reallocation of resources and funds considered reasons for this change.

"Many, many years ago when I was still a kid when they still had a properly functioning conservation department they actually if you had, if you had a lot of losses and stuff like that they actually did quite a bit of work." F03

"*Nature conservation in this country should have done it and long ago if you contact them if you had a problem they brought some cages and they caught them and relocate them far away… but, these people doesn't operate anymore, they don't even, if you say there's poachers they don't have fuel to come here so."* F07

"The amount of time that it takes to get people out to come assess the situation and the amount of time that it takes to get a erm what's it, a problem animal permit and whatever, it frustrates a hell of a lot of farmers erm and I, I totally understand it and people obviously take matters into their own hands because the Government is not going to cover their losses if they sit in and do nothing for four weeks, five weeks." N07

This, alongside a hunting ban on leopards in South Africa between 2016- 2018 and again in 2019 (*Environ.gov.za*, 2018), left some farmers feeling unsupported and left to deal with predator issues alone. Hunting permits were regarded by farmers in the study as a compensation of sorts for losses, and some farmers (n=7/20) expressed that the ban has removed the value of farmers having a leopard on their land.

"The leopard permits they stopped it- but what they've done now, they've made the farmers kill them just straightforward because they're not getting out something out for it put a price on it." F16

"For years leopard hunting was open, as soon as there's a price on somethings head it gets erm, what do you call it, I'm not going to kill every leopard on this farm if I know it's worth a hundred thousand

Rand per leopard, you're actually going keep them and manage the hunting on them and I think that had to do with the amount of leopard we have now. Erm I do think the fact that you can't hunt leopard anymore might, might count against the leopard numbers for the future because if there's no value and it's causing some people money due to damage it's going to get shot and shot because there's no way for them to monitor the hunting, it's just not going to get done legal, it's gonna get done illegal but it's not gonna stop where in the past when, when there was actually money to be made it was just so." F14

"If we can start to shoot leopards then I won't just kill them because I want to shoot them then I get money for them so I will tolerate 2 or 3 kills to shoot one and then the one that don't kill will roam and he won't bother me at the moment like I can't take the chance cause there's no compensation." F20

As a reaction to this perceived lack of government support, farmers can resort to conducting lethal control as a reaction to losses and suggested it was easier to take matters into their own hands. Retaliatory killing is therefore not just about livestock loss and use of the term retaliatory killing may present an oversimplified picture of lethal control (Inskip *et al.,* 2014). Other studies have found that the tendency to kill carnivores is not directly related to the number of livestock lost (e.g., Zimmermann *et al.,* 2005; Cavalcanti *et al.,* 2010). Kissui (2008) found that whilst hyena were responsible for killing the most livestock, lions were most vulnerable to retaliatory killings with the cultural traditions of pastoralists seen to exacerbate the killings of lions. Retaliatory killing is therefore influenced by internal and external social and cultural factors which need to be understood in order to understand the motivations behind carnivore persecution (Gebresenbet *et al.,* 2018).

Livelihood strategies

As well as livestock and crop farming, game farming was common within the study area, with 14 (of 20) farmer participants farming both livestock and game species. Use of the term game farming here follows Taylor *et al.,* (2016) and refers to the management of wildlife species on private farms for commercial purposes. Game breeding often occurs inside of fenced camps to protect animals from theft and predation as well as allowing for easier management (Taylor *et al.,* 2016). Despite increased protection for game, farmer tolerance towards free-ranging carnivores has significantly decreased as the game ranching industry has evolved (Pitman, *et al.,* 2017b). Support for this phenomenon occurring in the current study site was provided by an NGO participant who stated:

"Game farmers don't report losses to the authorities as a predator predating on game is not seen as a problem animal according to legislation. This results in many more predators been killed or removed illegally using cage traps, gin traps, poison baits and shoot and shovel." N10

Game species can hold high financial value, especially in comparison to livestock, which may increase the potential for farmer persecution of carnivores when game predation is suspected (Pirie, Thomas and Fellowes, 2017). Depredation on game species was reported to have economic consequences for farmers and therefore impacted on their overall tolerance of, and behaviours towards, carnivore species. Whilst the financial implications of livestock loss are well documented and have long been recognised as a major motivator for retaliatory killings (Bagchi and Mishra, 2005; Kissui, 2008), in areas where farms are multi-functional a broader approach is needed when considering the economic consequences of loss since game farming and livestock farming can have different financial consequences. Focusing on a single issue, such as the financial implications of livestock loss, may lead to missing or neglecting factors that shape people's behaviours and attitudes toward particular carnivore species.

"Actually two years ago 2017, I had one caracal caught 12 impalas in 8 weeks time and if you go it's ZAR1000 impala so one caracal cost me 12, 000 rand in 8 weeks." F10

"I'm talking about the sable, the game. It's expensive animals so you have to, if you lose one animal it's half a million rand. It was expensive, not anymore but we continue our strategy." F15

In addition to the value of the species lost, the financial impact of depredation was dependent on the farmer's income status and main source of income. Not all farmers were able to afford the same losses; those who engaged with multiple farming activities had diverse sources of income and were better able to buffer themselves against loss. These farmers rotated their main sources of income depending on the time of year, market demands and availability of resources (i.e., food/water). Variation of income increases farmers coping strategies and may help reduce the consequences of livestock depredation (Dickman, 2008).

"It depends erm, er sometimes it's the vegetables, sometimes it's er the cattle, when that rush was with the exotic game then we did fine with the nyalas and sables, it depends, at the moment this year, with the foot and mouth disease the cattle is down so, I have, ah I made er, a variety so you just can focus and just quickly move your business as the market needs." F20

Only six (of 20) farmers relied solely on livestock for their main source of income. Farms with sole reliance on one species of livestock were more likely to express negative impacts following livestock loss. One participant- using cattle as a source of pension- lost 7 (of 9) calves from the most recent breeding season and expressed uncertainty over what they were to do for an income.

"No income, what can I do now, nothing to sell now." F04

This follows other studies that have found people dependent on single livelihood strategies can be more hostile towards carnivores (Dickman, 2008). Similarly, different social-economic groups have been found to have different perceptions of carnivores due to their differing resilience to cope with losses; in this way wealthy commercial farmers will cope better than poorer farmers with smaller herds (Pooley *et al.,* 2017). The financial impact of livestock loss was also related to the purpose of the livestock. Farmers had livestock for a number of reasons including commercial breeding, personal meat consumption and as a pension. One participant purchased cattle for each of their grandchildren to build up an inheritance fund, loss of these particular animals subsequently had long term financial implications for multiple people. This impact reveals some of the hidden costs of livestock loss; hidden impacts can include reduced psychosocial wellbeing, disruption of livelihoods and food security, and can be felt long after the actual depredation event (Barua, Bhagwat and Jadhav, 2013). Acknowledgement by conservationists of the hidden impacts of loss is vital for both conservation and human well-being and must be addressed further to increase coexistence.

Livestock herd size varied according to farming purpose with herd size ranging from 11 to 1500. Typically, farmers are classified as commercial, communal or subsistence. The FAO (2015) defines a commercial farmer as one who produces agricultural products with the objective of making a profit, in comparison a subsistence farmer is defined as producing to meet personal needs with little surplus for bringing in profit. Communal farming refers to livestock farming practises that utilise shared land for grazing and may sell excess livestock for profit. One NGO participant described farmers with under 200 livestock as "bigger than subsistence but not commercial" (N016). However, many farmers in the study had herds of under 200 livestock but would typically be classified as commercial farmers due to selling to commercial markets and auctions. Commercial and subsistence farmers have been shown to differ in their tolerance of carnivores and tendency to conduct lethal control with commercial farmers holding more positive attitudes towards carnivores than subsistence farmers (Marker, Mills and Macdonald, 2003; Inskip and Zimmermann, 2009; Potgieter, 2016). However, this does not mean that they utilise more sustainable livestock management practices as they may have the means to access more resources to manage and extirpate wildlife (Kansky, Kidd and Knight, 2016). This raises the question as to whether general classification of farmers is necessary in HCC studies; of greater importance may be the understanding of how individual circumstances and capabilities shape perceptions of livestock loss.

Matter of place

Farmers were asked if there were any species they did not want to see on their farm. Five farmers reported that all wildlife can stay on the farm; reasons for this included religion and acceptance of nature.

"God put them there." F17

"Its nature, you just live with it." F08

These reasons highlight some of the factors that contribute to farmers overall tolerance of carnivores. If carnivores are seen to belong to God, some religious farmers may not feel they have the right to remove them. However, this contrasts with a study in Kenya, which revealed that Maasai who were evangelical Christians were much more likely to report a higher tendency to kill carnivores then those who attended other churches or none at all (Hazzah, Borgerhoff Mulder and Frank, 2009). As such, personal beliefs shape relationships with, and behaviours towards carnivores. Additionally, some farmers may feel they have the right to control carnivores that occur on their privately-owned property. Three farmers expressed that they would prefer to see no carnivore species on their farms at all.

"Literally if it got teeth and it eat meat you don't want it anymore." F07

"I would like to see no predators." F10

Some listed individual species that they would prefer not to have on their properties. Baboons were named by three participants with one describing a recent event in which their LGD was wounded by a baboon as the reason for this.

"I would prefer the baboons to get their move on after what happened to XXX yes, I would, I would prefer not having too many of them because obviously a dog's not erm physically able to win that fight it's so but it's, it's really after what happened to the dog which I, I would prefer them to go to a different place." F14

Other species named as being preferred not to occur on farms were domestic dogs assumed to be owned by poachers, spotted hyena, wild dog, lion, cheetah, leopard, crocodile and elephant. Leopard were more respected over cheetah due to their feeding behaviour:

"But ja, and a leopard is better also because he'll kill and he'll eat everything but sometimes, ja well sometimes we saw some cheetah also here but that's very rare…we don't see them but they are naughty, they get to a herd of sheep, they'll kill 10 of them. A leopard will kill one thing and eat it." F18

"The leopard will catch a calf and he will take a week to, to finish it and put it in a tree or in a bush and he will eat everything, if it has maggots but the cheetahs they will catch something today and if it's one, you know maybe three, four days he'll get hungry again but if it's four or five of them walking together like a bachelor herd they will catch something today and tomorrow again so but there is wild animals as well so it's not just the, the cattle but they will see what is easy." F08

This could suggest that risk perceptions, rather than actual loss, may have a significant influence on attitudes and behaviours towards to carnivores (Bhatia *et al.,* 2020). Whilst all study farms were within a 100km radius of each other, farms had different experiences with wildlife. This is supported by ecological data, for example, elephants are known to only occur close to the Limpopo River and PAs (Selier *et al.,* 2014), whilst free-roaming lions are only present in the Greater Mapungubwe Transfrontier Conservation Area (northern areas of the survey area) (Snyman *et al.,* 2018). In the southern parts of the survey area, the only large carnivores that remain are leopards, brown hyaenas and spotted hyaenas (Chase Grey, Kent and Hill, 2013). Cheetah sightings have been reported by ranchers in most of the Limpopo province (Marnewick, 2016), however, numbers across the study area are thought by conservationists to be low. Free roaming wild dog occur along the South Africa/Zimbabwe/Botswana borders (Nicholson *et al.,* 2020); a pack of wild dogs is known to move throughout the northern regions of the study area (van der Merwe, D, personal communication).

Despite not wanting to see some carnivores on their own property, some farmers expressed the notion that carnivores were nice to see in national parks.

"They're very nice but in the Kruger park not here. That's why there's how many parks in this country, they can keep them there." F07

This change in opinion towards carnivores depending on location was picked up on by one PAA participant:

"I mean the guys will lock up house over here and they'll go for holiday in the Kruger and they've got the Kruger right here but they don't want, those animals, they don't want elephant, they don't want leopard, hyena, this that whatever but they want to see them, so it's a very confusing one as well." N01

Carnivores may therefore be given different identities depending on who is considered to own or be responsible for them, and where they are located. Species can be both liked and feared as found by Goldman, De Pinho and Perry (2010) regarding lions in Kenya. This suggests that location and the species present in the area shape people's overall perceptions and tolerance.

Use of intervention strategies

Not all farmers (n=4/20) utilised non-lethal intervention strategies. Reasons why interventions were not used included the cost of strategies, not trusting strategies to work, failed attempts in the past, believing nothing can help and passing down of farming methods (learning from what the previous generation did). Variation in intervention use can be attributed to subjective norms and lack of use may reflect the owners' perceptions of how others think they should act (Eklund, Johansson, *et al.,* 2020).

"A lot of these methods are passed down from generation to generation so if someone's father did it then they do it, it's almost a learnt behaviour or learnt er response to predators and there's definitely a huge hate towards erm, towards predators in this country. I think it's just a learnt behaviour and it's a method that's been passed down from generation to generation that's why they, they tend to use them ja." N09

This follows the Theory of Planned Behaviour developed by Azjen (1991) which suggests that human intention to perform a behaviour is predicted by attitude towards the behaviour, subjective norms, external factors and perceived behavioural control. Subsequently, there are many factors, including social norms and belief systems, which may influence farmers' adoption of intervention strategies (Ocholla *et al.,* 2013; Amit and Jacobson, 2017). Despite all farmers considering carnivores as a threat to their livestock, it did not mean that they utilised available interventions, thus exploring the factors that may contribute to farmers' intentions to use interventions is vital for increasing coexistence (Eklund *et al.,* 2019). As well as differing in their use of interventions, there was high variation in effort invested in protecting livestock. This was appropriately described by one participant who made a distinction between livestock farmers and those that just have livestock:

"Actually I think you get livestock farmers and then you get people they just have livestock, there's a massive difference. They tell you, ja goat farming doesn't work and then you go to their goats and you see but this isn't goat farming, you've got goats but there's no farming going on here." F14

Not all farmers invest the same time and finances into their livestock which is likely to affect their use of, and investment in, interventions. Understanding these differences may help to explain why not all farmers are willing to employ interventions and the impact this may have on their perceptions of HCC.

2.3.3 Limitations

Whilst the study included a number of stakeholder groups, the COVID-19 pandemic cut short data collection which led to some missed stakeholder groups. For example, two potential participants working for Limpopo Economic Development, Environment and Tourism Department (LEDET) had been identified, but following the researcher's return to the UK in response to COVID-19 travel advice, those stakeholders previously identified did not respond to contact and after three attempts to contact them it was decided to exclude them from the study. Ideally communal and subsistence farmers would also have been included in the study and a group of appropriate farmers had been identified in Feb 2020. However, it was not possible to meet with them prior to leaving SA and online interviews would not have been feasible for them because of practical and logistical barriers. Future studies should aim to involve all relevant individuals.

2.4 Conclusions

HCC is not a simple matter; conflicts are complex and often involve a vast array of elements (Dickman, 2010). Understanding people's perceptions can therefore provide guidance as to how to foster tolerance and/or coexistence. The inclusion of different stakeholder groups revealed similarities and differences in their perceptions of the drivers and barriers to HCC. This was particularly evident in the different attitudes held in regard to carnivore population size. The majority of farmers (n=14/20) reported a belief that carnivore numbers were high and increasing, in contrast only one conservation stakeholder reported numbers were high, with the majority expressing concern that populations were decreasing. Furthermore, a number of farmers felt that eradication of carnivores was not likely, stemming from a belief that past persecution has failed to harm their populations on farmland. If local land users do not consider carnivore loss an area of concern, it is unlikely that measures to protect carnivores will be adopted and use of lethal control may continue. The opinions and difference in perception here could have serious implications for carnivore conservation and intervention use; if left unaddressed, differences in perceived population size will become a major barrier to HCC. This demonstrates that exploring the perceptions of all stakeholders involved in HCC scenarios is particularly important as stakeholders working within the same area can have different opinions of their landscape (van Heel *et al.,* 2017).

Interactions with carnivores were infrequent; carnivore species were rarely seen and not considered dangerous unless injured or cornered. Despite this, some participants desired the eradication of carnivores from their land and lethal control methods were reported to be used. This suggests that interactions played a limited role in shaping perceptions, rather perceptions of carnivores were shaped by cognitive biases for example, discounting bias. Farms in the study were often family businesses with household members taking on different roles to ensure success of the business. Other family members would regularly listen to interviews and make comments they thought relevant. Previous studies using qualitative interviews have tended to focus on the household head, but this may miss valuable information. For example, if one household member is in charge of admin and finances, they are likely to have a different perception of HCC to someone who is with the livestock daily. Subsequently, it is important to include all household members in HCC studies to understand full range of perceptions on HCC. If household members feel neglected or not heard, they may prevent conservationists from the property subsequently creating a barrier to HCC.

Farmers in the study demonstrated an understanding of carnivore behaviour. Local ecological knowledge could therefore be a valuable, and currently underused, source of information in HCC scenarios. Local ecological knowledge could be used to better understand which carnivore behaviours are considered desirable and undesirable to local land users. This would subsequently highlight areas which need addressing in HCC intervention scenarios. The use of LEK can simultaneously provide information to conservationists on carnivore presence and behaviour in human-dominated landscapes, this may be especially important in areas which are less well studied, harder to access, or where sources of information on carnivores is limited.

The use of grounded theory was a novel tool with which to consider the factors and connections among stakeholder perceptions of carnivores; many of which have not typically been explored or discussed in HCC studies. The current research demonstrates that previous studies may oversimplify HCC scenarios. Despite living and working within the same community, no two participants were completely alike in circumstance and the situational context that contributed to each participant's perceptions of carnivores were unique. Grounded theory helped to reveal commonalities and differences in experiences, exposing the personal nature of experiences with and attitude towards carnivores, and the means by which these may shape people's relationship with carnivores. In a multi-functional landscape, such as the study site, drivers and barriers to coexistence are not just about livestock loss and are constructed from numerous socio-cultural, political and economic factors. As a result, multidisciplinary approaches will be key in determining the drivers and barriers to coexistence and to ensure that these can be addressed in HCC intervention scenarios.

Chapter 3A: Stakeholder perceptions of success in human-carnivore coexistence interventions

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The research was conceived and developed by Chloe Lucas, with support from supervisors KWT, JA and SBH. Chloe Lucas collected, analysed and interpreted the data, and prepared the original draft of the manuscript, after which the supervisory team contributed to editing the manuscript and approved the submitted version.

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Abstract

Human-carnivore coexistence (HCC) on agricultural lands affects wildlife and human communities around the world, whereby a lack of HCC is a central concern for conservation and farmer livelihoods alike. For intervention strategies aimed at facilitating to achieve their desired goals it is essential to understand how interventions and their success are perceived by different stakeholders. Using a grounded theory approach, interviews (n=31) were conducted with key stakeholders (commercial livestock farmers, conservationists and protected area managers) involved in HCC scenarios in Limpopo, South Africa. Interviews explored perceptions of successful intervention strategies (aimed at increasing HCC), factors that contribute to perceptions of strategy effectiveness and whether coexistence was a concept that stakeholders considered achievable. The use of grounded theory emphasised the individual nature and previously unexplored facets to HCC experiences. The majority

of stakeholders based their measures of success on changes in livestock loss. Concern has been raised over the subjectivity and reliance on recall that this measure involves, potentially reducing its reliability as an indicator of functional effectiveness. However, it was relied on heavily by users of HCC interventions in our study and is therefore likely influential in subsequent behaviour and decision-making regarding the intervention. Nonetheless, perceptions of success were not just shaped by livestock loss but influenced by various social, cultural, economic and political factors emphasising the challenges of defining and achieving HCC goals. Perceptions of coexistence varied; some stakeholders considered farmer-carnivore coexistence to be impossible, but most indicated it was feasible with certain caveats. An important element of inter-stakeholder misunderstanding became apparent, especially regarding the respective perceptions of coexistence and responsibility for its achievement. Without fully understanding these perceptions and their underpinning factors, interventions may be restricted in their capacity to meet the expectations of all interested parties. The study highlights the need to understand and explore the perceptions of all stakeholders when implementing intervention strategies in order to properly define and evaluate the achievement of HCC goals.

3A.1 Introduction

Coexistence between people and wildlife has become an increasingly important component to many conservation efforts, and yet it is a concept without a universally standardised definition (IUCN SSC HWCTF, 2022). The complexity and highly contextualised nature of coexistence suggests that it may be best viewed as a suite of notions relating to the sharing of landscapes with wildlife, rather than a single, definable construct (IUCN SSC HWCTF, 2022). With this nuanced designation in mind, increasing the means for carnivores and human communities to share natural resources in a sustainable fashion is considered critical to the survival of many large carnivore species and vital for human livelihoods and global food security (Ripple *et al.,* 2014; Boronyak, Jacobs and Wallach, 2020). International interest in increasing coexistence (in its various forms and interpretations) with carnivores in agricultural areas has led to the development of numerous techniques designed to reduce livestock depredation (Miller *et al.,* 2016) but understanding the effectiveness of interventions intended to facilitate so-called human-carnivore coexistence (HCC), is of worldwide concern. If effective, interventions should lead to a reduction in livestock depredation and encourage species conservation thereby benefiting both humans and wildlife (Hazzah *et al.,* 2014; Lichtenfeld, Trout and Kisimir, 2015). However, studies show that the implementation of an HCC intervention does not guarantee ecological success nor benefit to humans (Bennett *et al.,* 2016). Despite research into different strategies designed to increase HCC, there have been limited attempts to document their success on a global scale and published information about evidence-based effectiveness of interventions against carnivores is limited (Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018; Khorozyan and Waltert, 2019, 2021). Interventions are primarily designed to reduce livestock loss, presuming that a reduction in loss will facilitate coexistence. Subsequently, studies of HCC intervention effectiveness tend to involve quantitative measurements of livestock loss before and after strategy implementation (Miller *et al.,* 2016; Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018), thereby focusing on the biological aspects of conflict reduction. Yet, the actual outcomes of HCC scenarios are shaped by diverse social elements (Naha *et al.,* 2014). Likewise, the long-term success of these initiatives relies on numerous factors including willingness to adopt intervention strategies and human behaviour changes (Zorondo-Rodríguez, Moreira-Arce and Boutin, 2019). Perceptions of carnivores are not based on livestock loss alone (Marchini and Macdonald, 2018), but perceptions do influence acceptance of mitigation strategies independently of scientific evidence (van Eeden, Eklund, *et al.,* 2018). It is therefore essential to understand how interventions are perceived by different stakeholders alongside the factors shaping these perceptions. Since conservation is as much about people as it is about wildlife, understanding or adapting ecological parameters in isolation of the human dimension cannot increase HCC (Bennett *et al.,* 2016). Social science approaches are therefore essential to understand the drivers and impacts of attitudes, tolerance and behaviour towards wildlife (Nuno and St John, 2015; Brittain *et al.,* 2020). In particular, grounded theory is an established method that allows concepts, categories and theories to emerge from the data (Glaser, 1978). This allows for in-depth exploration of stakeholder experience to generate theory. The current study adopted a constructivist Charmazian approach to grounded theory, acknowledging that the researcher holds prior knowledge; theory hence arises from reflexive interactions between the researcher, participants, and data (Charmaz, 2006). The study began with an open-ended question that identified the topic of HCC without making assumptions about it (Corbin and Strauss, 1990). Whilst the use of grounded theory is not limited to a specific discipline (el Hussein *et al.,* 2014) and given its ability to reveal in-depth views of participants (Charmaz, 2006) our study joins a surprisingly limited number of previous studies in utilising it in the context of HCC; (Rust, 2015; Margulies and Karanth, 2018; Bogezi *et al.,* 2019). As per practices for grounded theory studies, this paper does not focus on quantitative statistics but explores perceptions of HCC intervention success and the means of measuring it among a range of stakeholders involved in the use of livestock protection strategies in South Africa. Additionally, the factors that contribute to these perceptions and whether coexistence was a concept that stakeholders considered achievable were investigated.

3A.2 Materials and methods

This chapter utilises data from interviews and participant observation. The full data collection and analysis procedures are described in chapter 2.2. The full methods section were included in the published version of this chapter.

3A.3 Results

Thirty-one interviews were conducted in total: 20 commercial farmers, 7 NGO workers, 3 PAA and 1 private tourism operator. Interviews lasted between 20 minutes and 1 hour 43 minutes with an average length of 45 minutes. All interviews were conducted in one conversation. Quotes are used throughout the text; participant ID is provided after each quote. "F" represents farmers, "N" represents conservation stakeholders. The classification groups were based on the participants employment type and not their values, beliefs or ethos. It is recognised that some farmers will also undertake conservation work or hold conservation beliefs, whilst some conservation workers will also farm. The classification of stakeholder type is therefore caveated as being purely based on their primary source of income.

Participants ranged in age from 27 to 81, with an average age of 50.5 years. Of the farming group, participants were predominantly male (18M, 2F). The majority of conservation stakeholders were also male (9M, 2F); all PAA participants were male. Nine farmers had a higher education qualification (ranging from diploma to BSc). All NGO and PAA stakeholders had a higher education qualification (diploma to MSc). Farmers in the study kept sheep, goats and cattle; 8 farmed with more than one livestock type, 9 kept only cattle, 2 only sheep and 1 only goats. Herd size ranged from 15 - 1500. Farms had an average size of 2290.25 hectares. Three farmers did not use any intervention strategy, but others used electric fence kraals (n=6), kraals (n=7), LGDs (n=7) or herders (n=3). Multiple strategies were used by12/20 farmers. Use of lethal control methods (trapping, shooting and poison) was mentioned by 10/20 farmers. Period spent living on the farm ranged from 2- 72 years. Conservation stakeholders had spent between 1- 20 years in their roles.

Farmers in the study predominantly made their own decision regarding intervention implementation. The type(s) of intervention strategy used by farmers were not pre-determined or targeted by the researcher and therefore perceptions are likely based on a mixture of NGO-implemented and farmer-implemented methods, depending on each farmer's method(s) of choice. Some farmers were or had been, involved in a LGD placement program operated by an NGO. In the program, LGDs are placed with farmers who enter into an agreement with the NGO to cease all forms of lethal carnivore control on the property. However, not all farmers were known by conservation stakeholders and not all farmers had been involved in conservation initiatives. Protected area authority stakeholders did not place intervention strategies with farmers but may have worked with farmers and conservationists, as well as recommended interventions.

3A.3.1 Stakeholder measures of success

The majority of participants (n=23/31) measured success by a reduction in livestock loss (Table 3A.2).

Table 3A.1: Stakeholder measures of intervention strategy success emerged in two main categories; illustrative quotes are used to describe the categories.

Measure of Success	Illustrative Quotes
Reduction in livestock loss	"By the amount you lose, it's easy." F13 "Well I think the only measurement there is, is the amount of livestock that gets either stolen or eaten." F14 "We obviously just measure it by if no animals have been killed or maimed and there were before." N07
Change in potential for loss	"Don't find tracks inside our kraal, around the kraal." F05 "We can see, it's been very long since we had something come from outside inside." F15 "Well it keeps the predators out…and they're not in the veld and you keep them in at night when it's more dangerous." F19

Change in livestock loss was measured in a number of ways: numerical difference between losses before and after interventions, reduced number of incidents of loss or injury and increased percentage of livestock successfully raised from birth. Change in potential for loss was also considered a measure of success (n=6/31). This was measured in a variety of ways: seeing less carnivore tracks at kraals, physical separation of livestock and carnivores (e.g., fences), and increasing the energy required by carnivores to get livestock (e.g., kraals or guards). Two farmers stated that they considered success of HCC interventions to be unmeasurable. "It's one of those things you actually can't measure" F20. One gave the reason that success cannot be measured as it is impossible to not known what livestock losses would be without the intervention. The other did not give any reason for their perspective despite being asked. There did not appear to be any relationship between a participant's duration on the farm or in a conservation role, and their measure of intervention success. Specific success indicators were more diverse but showed commonalities between stakeholder groups. Measures of success and the relationships between them are shown in Figure 3A.2.

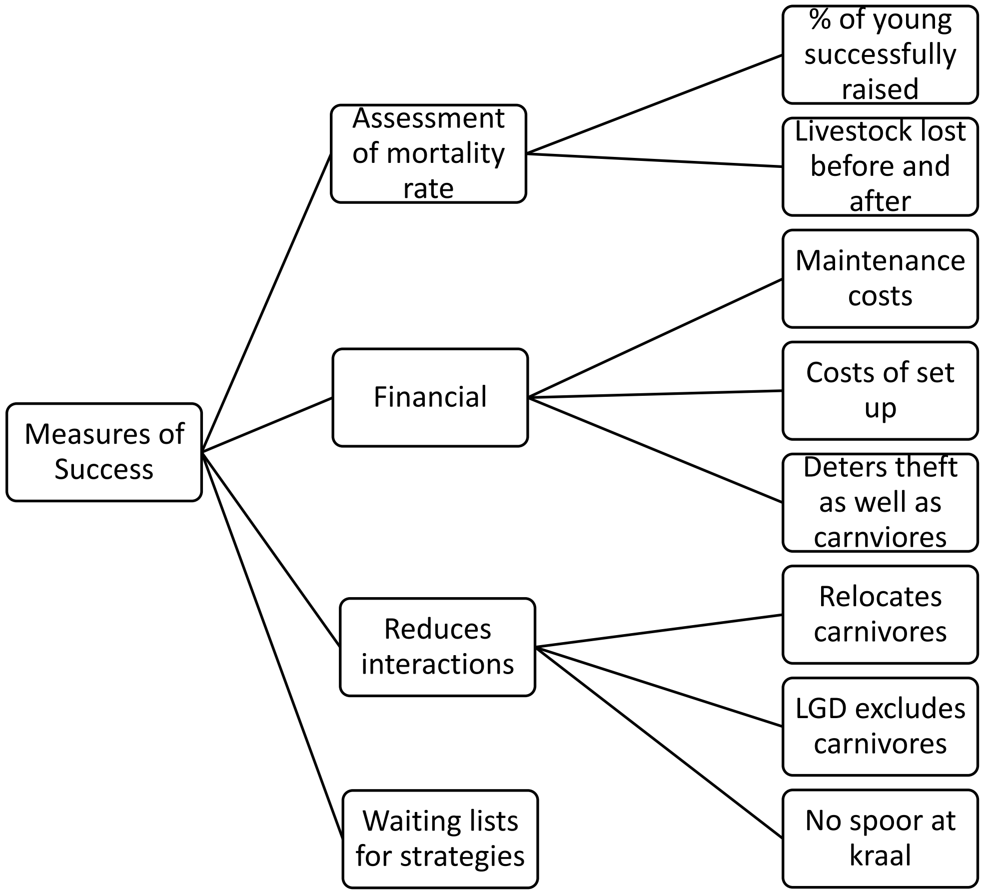

Figure 3A.1: Specific stakeholder measures of success for human-carnivore coexistence intervention strategies and their relationships.

3A.3.1.1 *Determining success*

Over half of the farmers (n=13/20) believed that only they can measure/determine the success of interventions. “I think the farmers because most of the info comes from us” Partner of F09. Other farmers determined success using reports from herders or farmer managers. Some NGO stakeholders based their measures of success on reports from farmers. “From the project side that’s who we take our cues from on ok this isn’t working or this working, so I would definitely say ja it’s basically the farmers themselves” N07. In contrast, two NGO stakeholders thought that it is scientists who measure success.

3A.3.1.2 Responsibility for achieving success

Over half of all participants (n=18/31) felt that the farmer was solely responsible for achieving success. “I’m the owner I cannot tell another guy it’s your responsibility, you know I must pay my salaries and I must you know make profit on the farm and so and so, no it’s my responsibility” F08. Two NGO participants reported that whilst most responsibility falls to the farmer, to succeed they must have support and collaborate with conservation organizations. “It’s the farmers main job but he has to have assistance from NGOs like us, there has to be collaboration between farming, the farming community and nature conservation organizations and the government nature conservation departments" N11. It was suggested by one conservationist that all stakeholders must take their share of responsibility to achieve success. One conservationist felt that farmers can want NGOs to take responsibility of intervention use.

3A.3.1.3 *Success feasibility*

All conservation stakeholders (n=11) thought successful intervention strategies were possible. However, a minority of farmers (n=3/20) felt that successful interventions were not possible. "There's nothing yet that was successful" F07. Farmer perception here appeared to be influenced by past experiences with different intervention strategies.

3A.3.1.4 *Factors shaping perception of success*

Three major themes emerged as factors that contributed to participants' overall perception of success: trust, word of mouth and acceptance (Table 3A.3).

Table 3A.2: Following a grounded theory approach and using data derived from 31 interviews, three major themes emerged as factors that contributed to perceptions of success. The categories emerged from the coding process and illustrative quotes are used to describe the themes.

Theme	**Illustrative Quotes**
Trust	"I mean the people keep on, keep on claiming we are, the farmers shoot them out, they have no idea what is going on in the bush…they have no idea what's going on." F20 The project is not here to be reporting people and that also damages the project to be quite honest in the sense of trust in the community, it's a very small community and ja if we break down trust with one person who knows how many more leopards will be killed and we won't be told about them whereas at least if we can kind of monitor slightly how many have been killed and how and why it gives us a bit of a better idea also to know ja basically what are we dealing and how we can [deal with it]." N07
Word of Mouth	"Somebody told me about it. Somebody told me and so then I phoned XXX and XXX made sure that I get one."F012

	“People who, who do use them (LGD) and use them successfully swear by them and that’s often how we get a lot more dogs out into those areas is, it’s very difficult as a greenie- they call us greenies, to convince farmers to, to trial other things, but if another farmer tells a farmer that he’s having a huge success with a certain method like dogs then generally other people are more inclined to utilize those things and that’s how, how we place a lot of dogs in, in South Africa is just farmers recommend them between farmers and that’s how we get a lot more dogs out there.” N09
Acceptance	“I wouldn’t have a problem if I lose let’s say a calf, two calves a year or something, I live in the bushveld this is nature, this is the way it is. If you farm in this area you must be prepared to live with it.” F08 “I think I will not go over 2%, I mean 2% is too much.” F19 “It might differ from farmer to farmer, erm some farmers are happy with a 8% livestock loss, some farmers can only afford a 5% livestock loss but they at least are willing to accept some sort of loss” N11

3A.3.2 Perceptions of coexistence

3A.3.2.1 Defining coexistence

Two phrases emerged as the most common ways to describe coexistence: “Live and let live”–was used by four farmers (F05, F13, F14 and F16). “Harmony” was also used by four participants: two farmers and two conservation stakeholders (Partner of F09, F15, N05 and N09). A common feature amongst participant’s definitions was an acknowledgement of being able to live in the same area and there being a place for people and wildlife. “Coexistence means that there, there’s a place, or there needs to be a place for each and everything. That’s coexistence, if I don’t have a place on my property for baboon or a place for a leopard then you don’t coexist” F10. “Well it’s living alongside with nature” N01.

3A.3.2.2 Perceived potential for farmer-coexistence to occur

Coexistence between farmers and carnivores was thought possible by the majority (n=22/31) of participants. “Most definitely, they can coexist. A farmer might give you a way different answer. Yes I believe they can coexist with predators, it will be harder but you need to understand your role within the bigger picture and then you can coexist” N06. “Ja of course you can, like I said there’s plans to be made without just killing everything, you can be a livestock farmer and have jackal or hyena on your property. You don’t have to kill them all” F14. However, not all participants (n=4/31) thought that coexistence between livestock farmers and carnivores was possible. “So in that stage [if farming crops] I think it’s possible but when there’s livestock I don’t think it’s possible”F07.“Not if you live from your farm animals you won’t because leopard is in nature to catch a calf erm the price is, if we get a lot of money for our cattle and you can have a good living then I think we can tolerate it but at the moment the prices are so bad so you cannot lose one” F2.

Population growth was considered a barrier to coexistence. “Not in Africa no, not with the er, not with the amount of human population growth erm no, it’s unfortunately not, it’s never going to happen” N09. Some participants (n=5; 4F and 1C) indicated coexistence to only be possible in reserves and protected areas. Whilst carnivores were considered to have a place within the South African landscape, precisely where this place was emerged in two opposing categories (Table 3A.4).

Table 3A.3: The initial and focused codes that make up the category of carnivores having a place in South Africa.

Category	**Focused Codes**	**Initial Codes**
Have a place	Acceptance	Part of bushveld Part of heritage Impossible to stop all loss
	Separation	Belonging in reserves Can go to neighbour Electric fence to keep out

3A.3.2.3 Factors involved in achieving coexistence

Four categories emerged as factors that will need to be addressed in order to achieve coexistence (Table 3A.5).

Table 3A.4: Following a grounded theory approach and using data derived from 31 interviews, four major categories emerged as being necessary to address to achieve coexistence.

Category	**Illustrative Quotes**
Support	“If we had more support from the government and it was easier to farm then we wouldn’t have gone to this extent to keep all the stuff out and kill all the stuff- Because yes you’re going to have damage, you’re going to lose some livestock but if you get money back from the Government or something like that then you say alright it’s not a problem, ok one is killed but ok well that thing needs to eat as well alright but don’t worry I’m getting something back but not you’re not getting something back so you have to look after yourself.” F10 “They have to accept that yes the guys with the teeth are there and we must do our utmost best to accommodate them as best as possible but to achieve that they would need support from either NGOs or Government departments to achieve that either through livestock or predation mitigation …. They, they cannot do it on their own erm they, they do, I think they do need help.” N11

Information Access	"But some of the people the local people don't have knowledge, that's why it's remaining a problem." F15 "I think a lot of it comes down to so ja basically what, what is that farmer wanting to invest so, so how important is it for him to ensure that predators and them can coexist, and then ja just education." N07
Respect	"Coexistence is a lot about respecting erm in your daily life, when you interact with, with people, for example. So you're not going to be respected, you're not going to get anywhere if you don't value what other people is also valuing. It might not be your values, but you need to understand the importance of those people's values to be able to coexist." N06 "They've got certain needs and I'm here and I've got certain needs too, and then we need to find a balance between both, I don't want to live in a sterile place where it's only me and my sheep left. I mean that's why we live here because of the diversity of animal life." F19
Mind-set Change	"I phoned XXX and there was 48 people before me waiting for dogs so…but so ja, there's definitely, I think there's definitely a movement towards this type of erm method." F14 "It's not like in the old days with the cattle farmers if they saw a track of a predator they will make a plan to get rid of it, nowadays the predators have a much better chance of making it" F16 "Slowly and convincing one farmer at a time yes, and working in important areas or corridor areas yes, erm but it's going to be a very long process and you know these livestock farmers unfortunately need to start seeing the benefits of having predators around as well and that is very difficult to show them." N09

3A.4 Discussion

Our use of a Charmazian grounded theory approach to exploring stakeholder perceptions of HCC intervention success and its measurement enabled a deep and insightful understanding of human-carnivore interactions in this South African rural community. The use of grounded theory provided an in-depth insight into the perceptions of different stakeholder groups, their interactions and communications. The richness of the data generated, and the subsequent theories that emerged from them have revealed new insights into the key factors involved in stakeholder perceptions of intervention success as well as the personal and context-specific nature of HCC. Whilst the majority of stakeholders used livestock loss to measure success, perceptions of success were not just shaped by livestock loss but influenced by various personal factors such as livestock type, herd size and source of income. Most participants felt that coexistence was achievable, four expressed that it was not. This kind of inter- and intra- stakeholder disagreement can have important impacts within a community or project area, even if they happen to be shared by only a minority. Such findings highlight the importance of understanding stakeholder perceptions of success and coexistence, as well as the factors that shape these perceptions. Understanding the social reality of the stakeholders is key to tailoring interventions to different scenarios in order to achieve optimal effectiveness for all involved

(Pooley *et al.,* 2017). For example, issues of power or authority and inequality (real or perceived) in economic circumstances or political representation/protection likely reflect in the varied individual circumstances and responses to HCC (Margulies and Karanth, 2018), as found in this study. In this sense, the individual circumstances explored here might be shared by many people but do not necessarily fully reflect the suite of situations arising from diverse economic and political systems. Exploring stakeholder perceptions through a political ecology perspective may therefore be beneficial to future studies of HCC scenarios.

3A.4.1 Measures of success

Farmers and conservationists were typically measuring success in the same way. Similar to other published studies, livestock loss was quantified in a variety of ways including number of livestock lost, percentage loss of stock, loss of stock per period or financial loss (Inskip and Zimmermann, 2009; van Eeden, Crowther, *et al.,* 2018), highlighting the reliance on livestock indicators by end-users of intervention methods. Furthermore, the use of change in potential for loss as a measure of success aligns with other studies investigating the potential for attacks, e.g., carnivore visitation rates (Miller *et al.,* 2016). The research bias towards using self-reported livestock loss as a measure of effectiveness, evident in current literature, has been widely criticised (van Eeden, Eklund, *et al.,* 2018; Ohrens, Santiago-Ávila and Treves, 2019; Khorozyan and Waltert, 2021), primarily due to its reliance on recall, and its lack of objective/empirical determination. However, our findings demonstrate this bias to exist at the grass-roots level and is not peculiar to the research community. Moreover, the majority of participants considered farmers as being the stakeholder groupable to provide livestock loss data, with very few considering scientific studies as a source of this information. The phrases used by participants from all stakeholder groups to describe measuring success with livestock loss (Table 3.2) include 'obviously', 'it's easy' and 'the only', indicating that this measure is a bottom-line argument; success is only about a reduction in livestock loss, and considerations about wildlife or people are not necessarily taken into account.

Use of reported reduction in livestock loss (i.e., relying on self-reported changes following intervention implementation to determine success) without a control group has been described as a measure of perceived rather than functional effectiveness and criticised as such (van Eeden, Eklund, *et al.,* 2018). Such reliance on livestock loss may be explained by availability heuristics (Tversky and Kahneman, 1973) in which livestock loss comes to mind most easily and consequently assumed to be most important when evaluating interventions. Despite this, some research has demonstrated links between levels of livestock loss and levels of predator removal (Ogada *et al.,* 2003; Shivik, Treves and Callahan, 2003). This suggests that whilst perceived reduction in livestock loss may not directly correlate with increasing HCC it is probably a key indicator (van Eeden, Crowther, *et al.,* 2018). In the current study, use of reduction in livestock loss to determine success was used by participants from all stakeholder groups and therefore may be the most relevant measure to develop shared perspectives of intervention success. If livestock loss is the measure used by farmers and determines whether or not a strategy is utilised, alternative measures of success may be meaningless to farmers and more abstract concepts more difficult to visualize, ultimately reducing engagement with HCC programs.

Concern has been raised over the use of farmer perceptions as measures of intervention success; i.e., the reliance on farmer recall or anecdotal records of changes in livestock losses may render these data less reliable than those collected under more controlled or purposefully designed experimental conditions. However, this stance may be overlooking the importance of these perceptions in driving behaviours relating to the wildlife or the use of (or decision not to use) an intervention. Likewise, if a farmer perceives the intervention successful (based on livestock parameters) and subsequently changes their behaviour or attitude towards carnivores, whether or not the intervention is functionally effective becomes redundant, so long as that perception is maintained. If success is determined by reduction in livestock loss as indicated by farmers and users are satisfied with interventions, the role of conservationists therefore may not just be to evaluate success but to concurrently help facilitate or measure changes in behaviour and attitude to ensure increased HCC. Arguably the role of conservationists then becomes one of managing perceptions, rather than focusing solely on scientifically objective measures. Indeed, the latter may even be counter-productive when stakeholder perceptions are firmly held or any level of mistrust exists between end-users and conservation or scientist stakeholders (see (Terblanche, 2020)). Having said that, the use of livestock parameters is entirely anthropocentric and does not consider the wildlife dimension of success. Livestock loss could therefore be described as a measure of potential for coexistence, but measures of wildlife occupancy and behaviour would be required in order to measure true coexistence. This suggests that a more nuanced and holistic or multi-dimensional approach to evaluating success is needed, especially when it comes to measuring long term success and sustainability. This scenario may also benefit from consideration of the influence of emotions, heuristics and biases within each stakeholder group; communication strategies which foster co-development of intervention methods and evaluation measures would likely be essential (Reed *et al.,* 2009).

3A.4.2 Perceptions of success

Whether success was perceived as achievable was associated with strong economic drivers; for all stakeholders, success was considered easier to achieve if the farmer was financially better off. Such perceptions, particularly by farmers, may indicate a feeling of success being out of reach financially if perceived costs are high. Additionally, it may also provide a reason or excuse as to why success has not been achieved. Moreover, slightly over half of participants (n=17/30) felt that measures of success must develop from the farmer themselves. Two NGO stakeholders expressed the idea that farmers must have NGO help to achieve success; in reality this is not a sustainable practice and may indicate a desire by NGOs to preserve or justify their own existence. However, it may also reflect a recognition of shared responsibility, attempting to ensure that the burden does not fall to farmers alone.

For the intervention to be considered successful, the costs of using and maintaining the method must enable local users to make a profit from livestock. Such perceptions of success may be reflective of the commercial nature of the farming participants such that subsistence farmer perceptions may differ. For some farmers, whether success could be achieved was dependent on the livestock species farmed; success was considered more difficult to achieve with cattle in comparison to small stock (sheep and goats). Kraaling of stock at night, when many carnivores are most active, was also considered a major factor in achieving success. However, five farmers did not consider kraals a successful method for cattle, reporting that it decreased their health, increased disease, increased costs of food and increased labour costs to bring cattle to and from the kraal. Whilst losses to small stock may be greater in comparison to larger sized cattle (Badenhorst, 2014), they were also considered easier to manage with interventions. The species farmed and livestock husbandry practices utilised may therefore affect whether farmers perceive that interventions can be successful. Other limitations to being able to achieve success included carnivore habituation, unwillingness to take responsibility, and a lack of financial means to invest in interventions. “Tried different things over the years bells and this and err I don’t...none of them in the long term it works, every little thing that you change works for a short while until the predators going to figure it out” F03. The duration of intervention effectiveness is an important characteristic of success evaluations (Khorozyan and Waltert, 2021) and represents a shared concern between stakeholder groups. Carnivore habituation to interventions occurs faster in human-dominated areas where they are likely to be more exposed to artificial novelties (Blumstein, 2016). Measures of success should therefore take into account habituation and consider whether success may have a time limit (Eklund *et al.,* 2017).

Unwillingness to take responsibility to achieve success may occur due to lack of resources or knowledge, it may also reflect antagonism between stakeholder groups in which the protection of wildlife is assigned to conservationists, or blame is levied at each other. “I mean the people keep on, keep on claiming we are, the farmers shoot them out, they have no idea what is going on in the bush...they have no idea what’s going on” F20.“Some of the farmers are very proactive and they will do a lot to try and protect their herds but other farms are not as proactive erm where they don’t really try and do they just blame everything on anybody else and ja it’s not, it’s not their problem and they just, they will just take care of it” N11. In such cases, carnivores can become viewed as problem animals associated with, and considered owned by, conservationists rather than being perceived as natural (Macdonald, Loveridge and Rabinowitz, 2010). This could negate the need to protect livestock as the problem perceptually belongs to others and conducting retaliatory killing could therefore be considered a way to spite conservationists (Terblanche, 2020). Furthermore, if the drivers for attitudes or behaviour towards predators are related to other stakeholders and not the predators themselves, interventions aimed at reducing livestock loss or changing predator behaviour will be worthless (i.e., unsuccessful) in facilitating coexistence. This emphasises the need to understand not only stakeholder-specific perceptions of the topic, but inter-stakeholder perceptions as a potential driver of conflict over (rather than with) wildlife (Redpath *et al.,* 2013).

Only farmer participants thought success was unachievable; this difference between stakeholder groups suggests that improved dissemination of information on successful interventions among the farming community is needed. However, it should also be considered whether conservation stakeholders are unrealistic in their expectations of achieving success or whether they may have a vested interest since without success being considered possible, their role becomes unclear. "You know if we could get towards farmers and, and predators to coexist in South Africa we'll have achieved something huge" N09. This may also be indicative of a belief that when a project succeeds, NGOs may assume the right to claim ownership but when a project fails it is reasonable to assign blame elsewhere. Additionally, there is also a need to better understand why some farmers perceive interventions as unlikely to be successful. Previous intervention failures and lack of trust in other strategies emerged as factors likely to be important in shaping such perceptions. The differences in opinion as to whether success is achievable demonstrate the role of qualitative approaches in exploring and understanding similarities and differences among stakeholder groups, as highlighted previously (Sutherland *et al.,* 2018).

Of particular note was a minority (n=3/20) of farmers who expressed the view that the killing of carnivores by LGDs was a sign of success. Killing or harming behaviours towards wildlife were not explicitly asked about in interviews and such LGD-interactions were not mentioned by 12 of the 13 LGD-using stakeholders interviewed. These LGD-wildlife interactions are reported in the literature (Smith *et al.,* 2020) and typically considered undesirable from an ecological or conservation perspective. However, from a functional livestock protection perspective, the prevention of depredation by any means (lethal or non-lethal) is regarded as a successful outcome of the LGDs use by farmers. The potential misalignment between farmer and non-farmer perception of LGD success parameters is of concern for a number of reasons. Lethal LGD-carnivore interactions may go unreported by farmers either for fear of causing conflict with wildlife-focused stakeholders, or because they are not perceived as a problem behaviour (i.e., the dog was performing its role). This represents a limitation to LGD evaluations, as well as any efforts by NGOs placing LGDs to identify and mitigate such behaviours. A balance must be struck between meeting the expectations of intervention users (which may include the removal or exclusion of predators from their property, e.g., by LGDs or fences) and the expectations of other stakeholders who may view such interactions less favourably. The extent and frequency of these interactions must also be considered; in scenarios where LGDs are highly targeted and defensive towards carnivores directly threatening herds they maybe justified as a more responsible means of livestock protection than indiscriminate poisoning or shooting, such that a low incidence of carnivore mortality associated with their use could be deemed tolerable (Whitehouse-Tedd *et al.,* 2020). However, evidence of their interaction with non-target species (Whitehouse-Tedd *et al.,* 2020) counteracts such reasoning. Moreover, in other scenarios the combined farmer and LGD-induced carnivore mortality was greater post LGD-placement compared with farmer only induced mortality prior to LGD placement (Potgieter, Kerley and Marker, 2016). Hence, including measures of human behavioural changes (or lack thereof) alongside outcomes of the intervention itself is essential for determining the extent of coexistence. In situations where interventions do not concurrently lead to desired changes in human behaviour, even a low incidence of intervention-induced cost to wildlife could be enough to increase wildlife mortality (or other form of negative impact) overall.

3A.4.3 Factors Contributing to the perceived extent of success

3A.4.2.1 Trust

Building trust and creating meaningful engagement between locals and conservationists is fundamental in understanding perceptions and achieving successful conservation outcomes (Waters, Bell and Setchell, 2018). Levels of trust between farmers and conservationist (NGO and PAA) stakeholders were diverse, with a minority of farmers (n=2) giving all conservation stakeholders the nickname 'greenies'. This suggests some inherent preconceived ideas about conservationists and their work which are based on a stereotype, potentially undermining their actions on the basis of being perceived to be driven by a particular broad agenda rather than a specific reality.

Conservationists by definition do not hold neutral roles, especially in the context of heightened human-wildlife interactions (HWIs) (Redpath *et al.,* 2013; Brittain *et al.,* 2020), and therefore it is important for conservationists to consider how they may be perceived by other stakeholders. To try and reduce or dispel any preconceptions in order to build trust, it is vital to be visible, transparent and have a presence in farming communities (Young *et al.,* 2016). Equally important is recognition by conservationists of their role as a stakeholder and whether preconceptions in the community may discourage open communication regarding local beliefs and practices (Muhar *et al.,* 2018).

Farmers may be supported by conservationists on the proviso that farmers will cease all lethal control on their property. Conservationists must therefore trust farmers to adhere to this and report any issues. Developing a productive relationship between stakeholder groups was thought by all stakeholder groups to take time, and farmers must have a certain level of trust in conservation stakeholders before asking for support. Good communication is vital in building a relationship and must be made using culturally appropriate terms that makes clear the expectations of all parties involved. Local socio-political customs should be acknowledged; for example, one NGO highlighted how they employed staff with differing backgrounds to work within different communities which helped increase trust and intervention uptake in their project. This is particularly important in a socially diverse country like South Africa.

3A.4.3.2 Word of mouth

Farmers were more likely to adopt and use an intervention strategy if another farmer had used it with success. Communicating the success of interventions via word of mouth between farmers is likely to have the biggest impact on uptake. This aligns with previous work in this farming community on the uptake of one specific intervention method (LGDs) (Wilkes *et al.,* 2018) and with psychological theory explaining the importance of subjective norms in influencing intention to use interventions, i.e. livestock owners behaving in a manner perceived to be socially acceptable (Eklund, Johansson, *et al.,* 2020). Here we heard about it from a friend of mine. He got a dog from XXX and he tell me I must phone XXX and ask for a dog because that dogs that dog he gets is protecting his goats" F06."If you place a livestock guardian dog and we go to the neighbour no, no, no I don't want a dog but give it a year or two, maybe three then he say ah man yeah I think I want a dog by now, I've had neighbours requesting a dog after 10 years because they see the success their neighbour had with these dogs" N11. Whilst this farmer-farmer communication offers a more direct and possibly more relevant or trustworthy source of information for intervention users (compared with that offered by conservationists), it also means that bad experiences with interventions are likely to be equally (or more) widely disseminated and could represent a barrier to wider uptake. "In a lot of areas I do know they have a bad name or reputation but it's for us to go into those areas and actually to place a few and then to be successful to, to show farmers that they do work and then, then generally you have a lot more success" N09.

The reputation (regardless of accuracy) of an intervention strategy can therefore spread quickly through farming communities and must be taken into consideration when implementing interventions and evaluating success. In cases where the reputation is erroneously based on rare instances of failures (perceived or real), this can have long-term implications for program uptake and could result in farmers choosing to avoid implementing a method that, in reality, is likely to have beneficial outcomes for them. Moreover, the method of determining success (or failure) is again important to consider. Whilst scientifically determined effectiveness (using objective and controlled experimental designs) are undoubtedly important (van Eeden, Eklund, *et al.,* 2018), perceived effectiveness may be more likely to be disseminated within the farming community via word of mouth. For interventions that have previously failed (and therefore deserve their poor reputation), choosing to avoid implementing that method is likely to be a sensible decision for farmers. It therefore becomes necessary for those responsible for implementing or advocating the intervention to either remedy it, or to replace it with a more successful one in order that trust be maintained between farmers and conservationists. It hence becomes equally important to address misinformation in order to retain or rebuild trust. In any scenario, open and honest discussion surrounding the causes for previous, perceived or existing failures, and integrating objectively determined effectiveness measures with end-user perceptions, is vital in order that farmers can make informed decisions. The sustainable use of any intervention is therefore reliant not just on its ability to function in the manner expected, but for its effectiveness to be communicated accurately and widely via trusted sources.

3A.4.3.3 Acceptance

The majority of participants from all stakeholder groups acknowledged that it is impossible to stop livestock losses completely; losses to carnivores were largely considered part of farming in the area. “If you start farming you must know you are going to have some losses that is part of life, part of farming yes” F02. However, there was also a clear discrepancy between stakeholder groups as to what is an acceptable level of loss. Farmers would typically tolerate low percentage losses, e.g. 1-2%.“Maybe one percent or two percent but if it gets more than that then you have to get somebody, if you can’t do it yourself, you must ask somebody to put a cage or relocate the animal or something like that” F02.“I wouldn’t have a problem if I lose let’s say a calf, two calves a year or something, I live in the bushveld this is nature, this is the way it is. If you farm in this area you must be prepared to live with it” F08. In contrast, conservation stakeholders felt that farmers need to be prepared to accept much higher levels of loss, even up to 10%, here again revealing an apparent mismatch between stakeholder expectations and perceptions of each other. “Unfortunately um a lot of these farmers, they don’t want to lose any animals to, to predation erm they have an unrealistic expectation of farming in South Africa, you know you need to almost expect at least 10% loss of your animals to predators and that’s not that bad actually whereas the expectation, well in South Africa they don’t tolerate 1%” N09. NGO stakeholders may potentially be out of touch with the reality of the situation, or have expectations that do not align with those of end-users. Nonetheless, highly individualised perceptions of acceptable losses were exhibited among farmers and appeared to be shaped by factors including herd size and dependency on livestock for income. Importantly, this farmer-specific variability was appreciated by some NGO stakeholders. For example: "It might differ from farmer to farmer, some farmers are happy with a 8% livestock loss, some farmers can only afford a 5% livestock loss but they at least are willing to accept some sort of loss" N11. In order to reduce retaliatory or preventative killing of carnivores, the point at which farmers become intolerant to losses needs to be understood (Crespin and Simonetti, 2019); this should form the basis for any intervention goal. Where farmers' tolerance for losses (i.e., the maximum number of stock they would be willing to lose) is considered to be unrealistic by conservationists, understanding and considering the drivers for the threshold becomes even more imperative. In these scenarios there may be non-biological factors at play that lead to a near zero tolerance for livestock losses, e.g., economic vulnerability, social conflicts, sense of disenfranchisement or empowerment, or redirected antagonism towards wildlife arising due to other socio-political circumstances, as documented in the Karoo (Terblanche, 2020).

3A.4.4 Perceptions of coexistence

3A.4.4.1 Defining coexistence

The overall themes emerging for "coexistence" within the stakeholder groups here were similar to those used in the literature, i.e., that coexistence occurs when the interests of humans and wildlife are both satisfied, or when a compromise is negotiated to allow the existence of both humans and wildlife (Frank, 2016). However, unlike the scientific literature in which the precise definition of coexistence varies considerably among HWI studies, stakeholders were broadly in consensus that coexistence relates to humans and wildlife being able to live together. This is particularly encouraging given that a common definition will facilitate agreed aims and goals. A shared understanding of coexistence should be key to any project aiming to increase HCC but has often been overlooked previously and risky assumptions made regarding stakeholder perceptions and definitions of coexistence.

3A.4.4.2 Feasibility of coexistence

The possibility for coexistence to occur was caveated by farmers, such that it was considered feasible only if their livelihood from the farm was concurrently viable. "I have a place for everything but if they cost me money or damage or something I'll try and keep them out the way without hurting them or killing them then you can, you coexist" F10. In line with a previously identified economic basis for intervention success, the farmers using phrases such as 'live and let live' or living in 'harmony' with nature, were also those that had multiple sources of income and did not rely on livestock for their main source of income. This diversity in income streams likely provided some buffering against economic impacts of livestock loss and appears intricately linked to the belief that some losses are an inherent part of the farming system. This follows other studies that found people dependent on single livelihood strategies more hostile towards carnivores (Dickman, 2008). This was reaffirmed when farmers indicating that coexistence was not possible Cited financial loss as a major barrier to coexistence; with participants expressing that if they were unable to make a living, they did not feel able to coexist with carnivores. To this end, livestock farming was considered unconducive to coexistence by its very nature, whereas crop farmers were perceived to be able to coexist with carnivores as their income would not be impacted by carnivores. "If you do it otherwise like crops I mean it's not a problem they don't eat veggies so it can but not with livestock no" F08. Such emphasis on financial factors were a common reason for not wanting to coexist with carnivores on farmland in previous studies (Lindsey *et al.,* 2013) and here suggest that it is not the carnivores per se that the farmers do not tolerate, but the outcome of negative interactions. However, in the current study, other factors such as the market price of livestock also affected how much carnivore-related loss farmers were prepared to accept and in turn whether they perceived coexistence to be feasible. This indicates that perceptions of coexistence are likely to be capricious over time as well as dependent upon a suite of individual circumstances.

More tangible and constant factors, such as livestock management and the use of interventions were also important in facilitating the perceived feasibility of coexistence. "By protecting your animals against them, like with a dog, so that they can't come and make damage...yes I think absolutely" F12. Some NGO participants took ownership of a perceived success in demonstrating coexistence. "Yes I think we've proved it in our project we, have proved it, it is possible erm for predators and farmers to coexist" N11. Whilst encouraging to see such positivity and claims of success, this brings the additional consideration of who is responsible for the success (or failure) of an intervention, and the possibility that such perceived ownership by one stakeholder may inadvertently disrespect reciprocal contributions by other stakeholders. Use of the term 'we' by the conservationist suggests a feeling of ownership over the project as well as responsibility for achieving coexistence, and contrasts with other NGO statements in regards assignment of blame. This may be indicative of a subconscious bias or underlying belief but, perhaps most importantly, it reiterates the need to acknowledge inter-stakeholder dynamics and their potential impacts on the ability for coexistence to occur.

Biological factors were also recognised by stakeholders and the availability of natural prey was recognised as playing a role in whether coexistence is possible. "I think we can live together but depends on the elements, if there's enough food, they won't catch each other but if there's not enough food, that's[quite] a problem" Partner of F09. Likewise, an increasing human population was considered a factor preventing coexistence. As the human population continues to expand, with the Limpopo province experiencing an annual population growth rate of 0.89% (Anon, 2016), HWIs have arguably become more complex (Frank, Glikman and Marchini, 2019) along with solutions to preventing conflict over wildlife. This factor may also be perceived as beyond the control of individuals, therefore putting 'success' further out of reach and influencing associated behavioural intentions accordingly. The sense of hopelessness expressed here suggests conservationists may feel they are fighting a losing battle. Such feelings could further exacerbate tensions between stakeholder groups but also influence their aims and what they would consider successful in coexistence goals. Expanding human populations and/or habitat fragmentation are often considered as major causes of increasing negative interactions between people and wildlife (Ocholla *et al.,* 2013).

In common with findings pertaining to the willingness to take responsibility and a perception that carnivores are owned by, associated with, or the responsibility of conservationists (i.e., not the farmers fault or concern), carnivores were considered "nice to see" in national parks or zoos but not on farmland. "If they are in like the Kruger National Park- I think you can live with them. But not here" Partner of F04. "The guys that want to protect them they must take them. I don't like them, go to the zoo if you want to look at them because we must live here and they make so difficult for us to live, to, to, to make a living so and these things stay they make it difficult for us to live here" F20. The somewhat paradoxical idea that separation between people and carnivores is needed for coexistence was reflected in one farmer's reason for using electric fences. "I put electric fence on so then they can't get in but I don't kill them so they can coexist outside, so yeah I would like them to disappear from this area and let them be in a different area and if I want to see them I'll go to that area" F10. Desire by farmers to separate people and carnivores as a means to achieve coexistence has been noted in other studies (Whitehouse-Tedd, Basson and Cilliers, 2021). However, the idea of exclusion contrasts with the perceptions of others from all stakeholder groups who considered carnivores a natural part of living in the bushveld, but often on the condition that they occurred without cost to farmers' livelihoods. Whilst spatial and temporal considerations were important in shaping perceptions of coexistence it could be argued that it is not true coexistence if people and carnivores are separated. This relates to the importance of using definitions and metrics determined to be relevant to the stakeholders involved. As such, the concept of co-occurrence (in which two or more species occur within one ecological community but without any direct interaction), rather than coexistence (in which interaction occurs but there is no net impact for either species) (Harihar *et al.,* 2013), may better define what many conservationists and farmers alike are striving to achieve in agricultural contexts.

3A.4.5 Factors involved in achieving coexistence

Whether coexistence is perceived as possible can depend on time and place. In conservation, this has resulted in debates regarding the concepts of 'land sparing' versus 'land sharing' (also known as wildlife-friendly farming) (Green *et al.,* 2005; Fischer *et al.,* 2014). Whilst protected areas are vital in carnivore conservation, many reserves in Africa are not large enough to maintain viable populations of wide-ranging carnivores and in order for them to survive they will need to persist beyond the borders of protected areas (Durant *et al.,* 2017). For those living on the borders of protected areas, tensions are often heightened and damage to livelihoods can reduce support for conservation initiatives(Anthony, 2007). Given the ever-increasing presence of humans across landscapes, coexistence with carnivores will require sharing land in many, if not most, contexts across the globe (López-Bao, Bruskotter and Chapron, 2017).

The notion that farmers must have support from conservation or government stakeholders in order for coexistence to be achieved was apparent across all stakeholder groups. Conservationists would likely benefit from working to gain farmers trust and provide support in a locally appropriate manner so that interventions designed to facilitate HCC are accepted and used. Likewise, farmers must be aware of (and have access to) the support available to them, along with knowledge of the available strategies and how best to utilize them to achieve the desired outcomes. Information about interventions should be made widely available in a format that is appropriate to local stakeholders. Stakeholders are likely to hold different values towards wildlife and it is particularly important for conservationists to advocate for wildlife in a way that respects local values and beliefs (Jordan *et al.,* 2020). In the current study, stakeholder groups acknowledged that whilst they may not have the same perceptions, they must respect each other's values to enable the collaboration needed to achieve HCC. If interventions are implemented without understanding and respecting the values of other stakeholders, conflicts between stake-holder groups could escalate and challenge attempts to increase HCC (Eklund, Johansson, *et al.,* 2020).

Interestingly, a change in farmers' mind-set was considered important by all stakeholder groups, including farmers themselves. This demonstrates farmer-reflexivity that has arguably been unacknowledged in the conservation practitioner and academic literature. Whilst historically farmers may have attempted to eradicate carnivores on their property, participants indicated that this was beginning to change, and the younger generation was now more willing to coexist with carnivore species. This is similar to other studies that found use of non-lethal interventions has increased relatively recently (Treves and Karanth, 2003). For this mind-set change, farmers must either be motivated to coexist with carnivores or to at least use non-lethal forms of livestock protection instead of lethal methods for other reasons (e.g., reduction of financial loss); in either case this must translate into a willingness to participate in achieving this. It must be recognised that changing people's attitude or tolerance towards wildlife is likely to occur slowly (St John *et al.,* 2018). Subsequently, changing even just one farmer's behaviour towards carnivores could be regarded as a conservation success, especially in light of our findings in regards word-of-mouth.

3A.5 Conclusions

Participants in this study predominantly measured success as a change in livestock loss as reported by the farmer. The use of livestock loss to determine success can perhaps be explained by cognitive biases in the form of availability heuristics which suggests that because livestock loss comes to mind most easily when evaluating success, it must be most important. Such cognitive biases may explain why livestock loss is a measure of success that can be understood by all stakeholder groups. Recent calls in the scientific literature for evaluations of HCC interventions to place greater focus on the use of controlled experimental designs and reduce reliance on farmer perceptions may not suit the interests of all stakeholders. Since stakeholder groups largely agreed that farmer-derived data on changes in livestock loss was the preferred measure of success here (and potentially elsewhere), assessing changes in attitude and behaviours a result of intervention use may be more important than assessing functional effectiveness to ensure interventions are achieving desired goals. Ownership and responsibility emerged as areas with potential for human-human conflict to arise and highlighted how sub-conscious biases may shape the perceptions of conservation stakeholders and whether success can be achieved. Furthermore, the role of conservation stakeholders must be considered in HCC scenarios, whilst their role is to help facilitate and enable intervention use (e.g., through promotion and distribution), ultimately the farming community will only use interventions they perceive as successful. Word of mouth among farmers emerged as the best method to share successes, demonstrating the importance of subjective norms in driving perceptions and use of interventions. However, farmer networks can also spread negative information about interventions and one failed experience can have wider repercussions which impacts perceptions of success. In such scenarios, neither quantitative statistical evaluations of farmer support for an intervention, nor treatment versus control studies, would be able to adequately relay this information and its potential consequences. In-depth qualitative studies highlight the impact that the extreme minority could have on achieving HCC goals. Furthermore, given the confidence placed in word of mouth for the dissemination of intervention success (and failure), the sustainability of any intervention's usage is dependent on the maintenance of perceived effectiveness. It is therefore likely that a combination of both perceived and functional effectiveness must be achieved for any intervention to be useful in facilitating HCC in the long-term. Given the grounded theory approach used in the study, it is not appropriate to extrapolate or generalize the findings. Nonetheless, although the findings of this study are primarily specific to this HCC scenario in South Africa, the fundamental principles of using intervention dissemination and evaluation parameters of direct relevance to end-users, as well as acknowledgement of the importance of inter-stakeholder discord and its resolution, as revealed here, can be applied globally. Moreover, the methodology is not specific to this context and a grounded theory approach would be a valuable addition to the study of human-wildlife interaction situations globally to draw out novel aspects of scenarios and gain a more in-depth understanding of stakeholder perceptions.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Nottingham Trent University School of Animal, Rural and Environmental Sciences Ethical Review Group (ARE880). The patients/participants provided their written informed consent to participate in this study.

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Chapter 3B: Stakeholder perceptions of different mitigation strategies designed to increase HCC.

3B.1 Introduction

Previously we determined that the 31 participants of the current study (20 farmers, seven NGO workers, three PAA and one private tourism/conservation operator) predominantly measured intervention success as farmer-reported changes in livestock loss (Lucas *et al.,* 2022 see chapter 3A). However, to further understand the use of interventions aiming to facilitate HCC, it is important to explore stakeholder perceptions of specific interventions, why they are (or are not) considered successful, and factors associated with this success (or lack thereof). This is essential as interventions can only provide a reduction in predation and increase HCC if they are considered successful, accepted, and used by livestock owners (Eklund, Johansson, *et al.,* 2020). If successful, interventions have the potential to mitigate discord between those with conservation interests and those with an interest in livestock husbandry (Riley *et al.,* 2002; Redpath, Bhatia and Young, 2015). Exploring stakeholder perceptions of different interventions can therefore help to identify areas of agreement and disagreement between stakeholder groups, and better understand which interventions are considered acceptable, which are not, and by whom (Redpath, Bhatia and Young, 2015; van Heel *et al.,* 2017). For example, it has previously been found that interventions such as livestock guarding animals and night enclosures that are believed to be effective by livestock farmers can have a low tendency for acceptance amongst farmers (Eklund, Johansson, *et al.,* 2020). It is consequently essential to understand how stakeholders perceive different interventions as well as the factors that contribute to their perceived success and subsequent use. Chapter 3A explored how stakeholders in the study define and measure success, this subsequent sub-chapter expands on that to explore perceptions of different intervention strategies and the factors that contribute to their perceived success or lack of success.

The sub-chapter aims to:

- Determine the perceptions of different HCC intervention strategies used by participants to prevent undesirable livestock-carnivore interactions.
- Identify factors that contribute to the perceived success/ failure of specific HCC intervention strategies.
- Explore inter-stakeholder variation in perceptions of different HCC interventions.

3B.2 Methods

This chapter utilises data from key informant interviews, grounded theory semi-structured interviews and participant observation. The data collection and analysis procedures are described in chapter 2.2.

3B.3 Results

Thirty-one interviews were conducted in total: 20 commercial farmers, seven NGO workers, three PAA and one private tourism operator. Farmers in the study used a variety of intervention strategies including non-electric enclosures (n=7), electric fenced enclosures (n=6), livestock guardian dogs (LGDs) (n=7) or herders (n=3). Livestock enclosures are known as kraals by participants in the study and hereafter referred to as such. Use of lethal control methods (trapping, shooting and poison) were not specifically asked about, but use was voluntarily mentioned by 10/20 farmers. Three farmers did not use any intervention strategy. Multiple strategies were used by 12/20 farmers.

The researcher did not target a specific type of intervention strategy used by farmers and therefore perceptions are based on a mixture of farmer-implemented and NGO-implemented methods. However, at the time of interview, 13 (out of 20) farmers reported on LGD use. Given its prevalence among the study participants, further details of this intervention are provided; seven farmers had at least one LGD, four had previously had a LGD while two had family members with or who had previously had an LGD. Some of these were or had been involved in a LGD placement programme operated by an NGO. Other LGDs had been sourced by the farmer themselves. In the LGD programme operated by the NGO, farmers entered into an agreement to cease all forms of lethal carnivore control on the property when the LGD is placed. For the first year, the NGO provides food and veterinary supplies as well as monitoring and training. After this point, responsibility for the LGD is handed over to the farmer.

In regards the inter-stakeholder relationships held by participants in the current study, the seven farmers with LGDs in the study were known to have had prior or current engagement with at least one conservation NGO in the region, and which was also represented by at least one participant in the study. However, not all farmers had participated in conservation initiatives or were known to conservation stakeholders. Protected area authority participants did not implement interventions but may have recommended strategies and worked with farmers and conservationists, but the nature of these relationships were unknown.

Quotes are used throughout the text with participant ID provided after each quote; the prefix “F” is used to represent farmers and “N” represents conservation stakeholders. It should be noted that classification in this way was based on the participants occupation alone, and not their values or beliefs.

3B.3.1 Perceptions of different HCC intervention strategies

Participants in the study perceived the use of LGDs, kraals, herders, and lethal control methods to be successful (Table 3B.1). Combining strategies, e.g., LGD and kraal, or LGD, herder and kraal, was perceived by participants from all stakeholder groups as the most successful way of preventing livestock loss.

"*I think it's successful because it's a combination of things, if you only do one thing it will not be sufficient but because it's a combination of things, I think that's why it's successful….Not only one thing will do the trick because we had only the electrical fencing and it did not do the trick so a combination of stuff because when one fails the other one helps, I don't know but I don't think one will suffice."* F13

"*It's either going to be electric fence or then at night-time they have to sleep in a kraal with an Anatolian dog, I think that's the best, I think we had really good success with the dogs*." F10

The majority of farmers (n=13/20) used kraals at night and viewed this as necessary to protect livestock. Night was considered the most important time to protect livestock as carnivores were reported to hunt at night.

"*All of them they sleep together in a kraal each and every night 'cos er when we didn't do that, we lost three calves in a row."* F05

However, a minority of farmers (n=2) reported losing livestock from kraals and subsequently stopped using them. Five farmers expressed concerns about the use of kraals for cattle and did not consider them a successful method for cattle. It was reported that keeping cattle in kraals at night decreased the cattle's health, increased disease, increased costs of food and increased labour costs to bring cattle to and from the kraal. Six farmers used electric fenced kraals and considered this necessary for achieving success; one farmer reported that prior to installation of electricity, carnivores would pass into the kraal.

"*One year the jackals took out of this kraal 40 lambs, killed in one year… Ja, they just went underneath…I've put the electric fence also around this now so electric fence also help*." F09

In contrast, three participants (F=1, N=2) from the farmer and conservation stakeholder groups, voiced concerns about electric fencing causing harm to other wildlife species.

"*Electricity is a bad thing because they kill the tortoises."* F16

Herding was considered by four (of 11) NGO and PAA stakeholders as a successful method at reducing livestock loss. In contrast, only three (of 20) farmers mentioned the use of herders as a strategy to reduce livestock loss. One farmer reported having a herder but considered their role as being to ensure livestock did not stray to neighbouring properties and returned to the kraal every evening.

Lethal control methods (shooting, poison and cage traps) were considered by half of farmers (n=10) as a successful way of removing problem causing carnivores.

"*Sometimes I use the trap, sometimes I use poison, sometimes I hang up poison it depends, erm and sometimes you get a leopard that don't want to take bait, then you set a gun up for it- put a gun up, he walks in and you shot it."* F20

Farmers in the study were aware of the legalities surrounding the use of lethal control methods but considered their use easy to hide from authorities.

"*I know it's against the law but are the law going to pay me out for the cattle that he caught*." F04

"*I will just keep quiet, if someone says did you kill a leopard, I'll just say no I don't."* F07

Respondents from all stakeholder groups suggested that the use of lethal methods has reduced over time.

"*It's better than for the wild animals nowadays than it was in previously because of all the erm information and things available, you would try and erm to work together not kill them maybe find something better but in the older times they just shoot it straight yes*." F02

A total of 13 (out of 20) farmers reported on LGD use; one farmer raised questions about the use and success of LGDs and how their presence may affect leopard behaviours:

"*In the near future I would say the dogs would still be effective like I said earlier, I don't know what's going to happen erm with say the leopard population if it's a bigger and bigger area that gets filled with these dogs, where would the leopard go? They're just going to figure out a way of getting past the dogs and this and that and then they're just carry on again."* F03

Three farmers mentioned that they had previously used bells on livestock but did not consider this a successful intervention for reducing predation. Five participants (3F, 2N) mentioned that they had heard about livestock collars being used to protect livestock, however, none had tried it and all five perceived the strategy unlikely to be successful. Five farmers reported that they would like to receive compensation from the government for livestock losses.

Table 3B.1: Using a grounded theory approach and data derived from 31 interviews, participants reported on the use of LGDs, kraals, electric fenced kraals, herders and lethal control methods. Reasons as to why these HCC interventions were perceived as successful and unsuccessful are provided alongside each method.

Intervention	Reasons stated why successful	Illustrative positive quotes	Reasons stated why unsuccessful	Illustrative negative quotes
Livestock guardian dog (LGD)	Cost effective Deters theft as well as predation Can combine with other methods Protects entire herd Can be used for different livestock types Work long-term Can have multiple LGDs- older dogs help train new dogs Barking at night provides reassurance Kill threats to livestock	"I don't know how you farm in this area without the dog, I'm honest, I've got no idea how you can." F14 "Now that we have this Anatolian, they, it's a total different thing. I never realised that one dog could make such a big difference." F13	Lack of training Personality of LGD Age of LGD LGD could get injured, poisoned or stolen	"You know not all dogs work, we found that only 80% of dogs that we place become successful livestock guardian dogs so it's another thing you need to take into account, not every dog develops into a successful working dog." N09
Kraal (non-electric)	Provides protection at night when livestock are most at risk Keeps livestock together Separates livestock and predators Proximity to people/house	"You've got hyena, you've got jackal, you've got leopard and they're all nocturnal animals so it's… Ja, you have to kraal them at night." F14 "It costs you a little more to keep the stuff in	Leopard can climb Keeping in kraal requires supplementary feeding Does not work for all species Cannot kraal large herds	"One year we lost 7 calves out of that pen there right next to the house basically so how effective is that." F03 "We don't keep the cattle in the kraal during the night so when they're out there the cattle is also

	further deters carnivores	the kraal but it's worth it." F06	Can increase disease Moving livestock to kraal requires labour	in the field and most of the people try to tell you but keep them in the kraal, now if you have to work with the cattle they're for two days without food because they're in the kraal for the night and the next morning you start with the cattle so and you've got a hell of a loss because they're not grazing, weight loss." F07
Electric fenced kraal	Electric adds extra protection Can combine with other methods Separates livestock and predators Covers costs in the long-term Deters all predator species	"It's expensive to put up electric fence but I think in the long run it will pay for itself." F10	Electric fence harmful to other wildlife Expensive to install and maintain	"It has very bad side effects on wildlife so if you want to save you know predators and on the other side you destroy reptiles and birds and all that is it really, so I think, I don't think electric is a solution" N03
Herder	Human presence deters carnivores Cost effective Report incidents to farmer	"I've got three herders… with the goats every day. Saturdays, Sundays yes because we can't feed these goats over the weekends it's a lot of food so they go every day." F09	Dependent on attentiveness of herder Labour costs expensive	"We tried to get er guys to stay with the herding and this and that, not with the cattle obviously but with the goats and stuff but that also didn't work" F03

Lethal Control	Quick, easy and cheap Easy to hide from wildlife authorities Can be used reactively, rather than preventively	"I know it's against the law but are the law going to pay me out for the cattle that he caught." Partner of F04 "At the end of the day you just sort the problem out now yourself because it's, it's not to go now to the, to go and sort out the problem and to try ask for a permit it's, there's just too much red tape" F08	Difficult to catch [in cage traps] May not remove problem Can cause mesocarnivore release	"I've tried a lot different types of traps and stuff but I think my success rate is really low and it's a lot of effort" F10.

3B.3.2 Factors contributing to perceptions of HCC intervention strategies

Several factors emerged as shaping participants' perceptions of different intervention strategy's success. These were economics, past experience, multi-functionality, ability to separate livestock from carnivores, ease of use, herd size and type, duty of care, and understanding the environment (Table 3B.2).

Table 3B.2: Factors that emerged as contributing to perceptions of intervention success following a grounded theory approach using data derived from 31 interviews.

Factor	Focused Codes	Illustrative Quotes
Economics	Installation Maintenance Long term costs Increase in labour costs	"It costs you a little more to keep the stuff in the kraal but it's worth it." F06 "She's [LGD] worth every penny, you can't, I can't even believe people would say ja it's expensive to look after them, I mean, I feel you should give her the best food you can." F14
Past Experience	Losses whilst using interventions Previous use	"One year we lost 7 calves out of that pen there right next to the house basically so how effective is that." F03

	Passing down of husbandry practises	"It was one of all that tricks, everyone said ah it's [get a] dog but 40'c that dog doesn't work, go anywhere, just lying in the water." F07 "I think it's just a learnt behaviour and it's a method that's been passed down from generation to generation that's why they, they tend to use them." N09
Multiple functions	[In addition to the protection of livestock]: Protect against theft Protect LGD	"It [the LGD] will protect them against human theft and all that, because the one that I got now I'm very sure nobody will enter that kraal at night, at night-time." F12 "I would definitely have a shepherd and that's also not only from kind of like the animal side of things, that's from stock, stock theft side of things." N07
Separation (of livestock and carnivores)	Fence use creates barrier Predators cannot access at night Removal of problem (separate through lethal control)	"They can't get in because I've got electric around." F10 "There was one time there was one leopard inside [the fences] but he's not inside anymore." F15
Ease of use	Quick fix Prevention rather than cure Short term solutions due to loss Financial input Time investment Training required	"Go out and shoot something erm but they ja, so ja poisoning and, and, and shooting is, is, I, it's the easiest and the quickest for the farmers" N020 "Some farmers see it as a quick fix, they want the dog to be out working from day one to make sure that they get, they resolve their predation problem as quickly as possible". N11
Herd Size and Type	Smaller herd easier to protect Small stock easier to manage	"Smaller quantities ja that's controllable." F11 "The only thing you can do is put them in, in a kraal here in a safe place here close at home but it's unpractical if you're a stock, er a cattle farmer and if you've got lots of cattle it's not practical." F18
Duty of Care	Maintenance of strategy Training [of LGD]	"They sleep together in a kraal each and every night 'cos er when we didn't do that we lost three calves in a row." F05

	Willingness to take responsibility Monitoring- prepared to adapt and/or amend	"But you have to monitor the whole time, if you leave it [the fence] it's not going to work." F15
Understanding of environment	Awareness of mesocarnivore release Lethal control creates gaps Fence use is unnatural Electric fences cause mortalities	"Electricity is a bad thing because they kill the tortoises." F16 "I know a fence is also not keeping everything out… and it should also not because you've got the ecosystem that you have to look after." N06 "If I go out and I shoot the male, the dominant male leopard on this farm I can promise you, within a month there's four young males on this farm trying to get this territory." F14

3B.4 Discussion

3B.4.1 Perceptions of different HCC intervention strategies and factors contributing to perceived success

The use of grounded theory to explore perceptions of different HCC intervention strategies revealed a wide range of opinions among stakeholders. Whilst no strategy was unanimously considered to be unsuccessful, all strategies had perceived issues which could prevent their use. Notably, it emerged that use and perception of specific interventions were highly personalised or context specific. For example, some farmers viewed electric fences as necessary whilst others viewed them as unaffordable, similarly labour costs prevented some farmers utilising herders whilst others preferred to invest in herders. Despite differing perceptions on whether specific interventions were successful, participants from all stakeholder groups agreed that combining intervention strategies (e.g., kraal and LGD) as the most successful way to protect livestock and reduce predation. Combining methods was not only thought to help reduce the risk of predation but to deter theft, which was commonly reported by farmers as a major limitation to livestock production (see chapter 2). Such perceptions are similar to previous studies which noted that farmers combined the use of different interventions, e.g., using a livestock enclosure with dogs and/or guns to shoot into the air if predators approached (Ogada *et al.,* 2003). Using a combination of two or more interventions has also been found to result in a significant reduction in livestock losses (Gehring, Vercauteren and Landry, 2010), which was the predominant measure of intervention success used by participants in the current study.

LGDs

The use of LGDs is growing in popularity among farmers and conservationists, and in southern Africa in particular, LGDs have been promoted as a means of reducing livestock loss on both commercial and subsistence farms (Marker, Dickman and Macdonald, 2005; Potgieter *et al.,* 2013; van der Weyde *et al.,* 2020). In this study, the presence of an LGD was perceived to reduce livestock loss (of all species) to carnivores therefore rendering the method as successful. One farmer also specified that having a successful LGD removed the need to use lethal control, demonstrating impact in regards human behaviour change. The success and popularity of LGDs in the study area was reflected in there being waiting lists, as reported by farmer and NGO participants, for LGDs from reputable breeders and programmes.

However, for success to be achieved with LGDs, it was noted by conservationists that both the LGD and farmer must be trained (see chapter 3A). Previous studies have found that LGDs may be ineffective in areas where proper dog training is not customary (Khorozyan *et al.,* 2017). Therefore, in order to achieve success, the organisation placing the LGD must give the farmer adequate training and ensure that their role in training the LGD is understood. Despite the majority of participants considering LGDs to be successful, it was recognised by conservationists that not all farmers are successful at working with LGDs and not all LGDs are equally successful at reducing losses (see chapter 3A). Again, this reaffirms the notion that intervention success is individualised and context dependent.

Nonetheless, the majority of LGD using farmers in this study considered the costs of LGDs worth it. Similarly, studies in the USA and Namibia show that livestock farmers perceived LGDs as a practical and economically viable means of reducing livestock loss (Andelt, 2004; Marker, Dickman and Macdonald, 2005). However, the possibility exists that some farmers may feel unable to afford the food and maintenance cost since these costs associated with LGDs have previously been considered 'significant' (Horgan *et al.,* 2020). Food costs have been estimated at $268-750 per year for Anatolian shepherd LGDs in Namibia (Rust and Marker, 2014) and a study in the USA reported that costs exceeded benefits over a 7-year working lifespan (Saitone and Bruno, 2020). Furthermore, the labour costs associated with utilising LGDs have been found to vary greatly depending on farming operation type and management system (Macon and Whitesell, 2022). It should also be noted that LGDs placed by conservation NGOs are often subsidised by the organisation for the first year which may provide incentive for many farmers to try LGDs as a strategy without needing to fund the initial costs, but transfers the financial burden to NGOs (and their funders).

Interestingly, the presence of LGDs were considered effective in reducing livestock theft as well as depredation. This dual role was expressed by farmers and conservationists as a key reason for LGDs being perceived as successful. The use of LGDs can therefore provide psychological reassurance to farmers as they can visibly see, and hear, that their livestock is being protected from multiple threats. However, theft and injury of the LGD was also of concern. Combining the use of a LGD with the kraaling of livestock at night or electric fences was viewed as a way of alleviating some of the anxiety surrounding LGD injury, poisoning and/or theft.

One of the major limitations to LGD success was concern over the ability of the dog to continue working as it aged. Participants expressed that the long-term success of LGDs was not guaranteed, emphasising that they can only be successful if they are healthy (i.e., able to carry out their role). In Namibia, the average lifespan of LGDs was found to be 4.8 years, with a maximum age of 14 years (Marker *et al.,* 2020). Similarly, a study in the same region as the current study determined the average working life of an LGD was approximately 3.75 years, and reported that a number of dogs died prematurely or were removed from their placement for behavioural reasons (Whitehouse-Tedd *et al.,* 2020). To combat concerns about LGDs working age and lifespan, three farmers had multiple dogs or were considering getting another. It was thought that older, more experienced dogs were most successful and training puppies with older dogs was the best way of ensuring protective behaviours were continued. This perception parallels with a previous study in Italy that found older LGDs remained closer to the herd and suggested that the bond between livestock and the LGD increases overtime (Zingaro *et al.,* 2018), hence the view that training puppies with older LGDs may increase their chance of being successful.

It emerged that all stakeholder groups may share similar questions and concerns about the ecological consequences of LGDs (for example, one farmer questioned where leopards go if all properties have LGDs). Such concerns have been discussed in the literature (e.g., Smith *et al.,* 2020; Spencer *et al.,* 2020) but the question here by farmers suggests that dissemination of these findings outside of academia is lacking. Other comments reflect concern that the LGDs may become ineffective if carnivores such as leopards learn to get around the dog. The concerns raised in this study are entirely valid and have not thus far been proven wrong or eliminated. Predator exclusion and wildlife harm by LGDs have been reported in many studies (Gehring, Vercauteren and Landry, 2010; Santiago-Avila, Cornman and Treves, 2018; Smith *et al.,* 2020) and is also reflected in the reports of farmers considering incidents of LGDs killing wildlife to be a sign of success (see chapter 3A). Conservationists therefore have a responsibility to address these concerns and mitigate harm to wildlife, whilst also ensuring relevant information regarding carnivore responses to LGD presence is communicated to farmers. It should also be considered whether it can be described as true coexistence if LGD use involves a form of exclusion or separation, i.e., preventing predators from accessing certain areas.

Enclosures (kraals) and fencing

Kraals are widely acclaimed by conservation researchers as a solution to prevent livestock losses to depredation (Khorozyan and Waltert, 2021) as they physically separate livestock and carnivores temporarily at night when carnivore species were thought to be most active. Similarly, in a study by Brink *et al.,* (2021), the majority of respondents believed that infrastructures such as fences and enclosures were most successful in reducing livestock depredation. If culturally accepted as a method of livestock confinement, kraals have been found to be highly successful at decreasing night-time livestock losses (Lichtenfeld, Trout and Kisimir, 2015). In addition, it was felt that kraals near to human activity or buildings were more successful at reducing losses. However, the costs of effective fence installation and maintenance may make using the strategy unachievable for some farmers (Brink *et al.,* 2021). Whilst physical separation between livestock and carnivores may be regarded as a means of increasing HCC, the use of fences and enclosures should only be considered successful if separation is accompanied by a change in human behaviour (namely to reduce persecution) and carnivore movements are not disrupted by fence use. The potential paradox posed by the use of separation of livestock and carnivores as a form of coexistence is discussed elsewhere (Chapter 3A).

However, a minority of farmers did not consider kraals a successful method due to losing livestock from within the kraal, illustrating how past experiences shaped perceptions of strategy success and subsequent use. Furthermore, some farmers did not view the use of kraals as suitable for all livestock species, especially cattle. Keeping cattle in kraals was perceived to decrease health, increase disease, as well as increase labour and food costs. As such, perceptions of kraal success were consequently dependent on livestock type, herd size, location of kraal, labour costs and funds available to maintain kraals. The varied perceptions on kraal use further emphasises that the success of interventions is highly localised and context dependent (Zimmermann *et al.,* 2021).

A minority of farmers reported that non-electric game fences were totally ineffective and that to achieve success electricity was essential. Electric fences are used in South Africa for a number of reasons including to protect livestock and game species from humans and carnivores (Hayward *et al.,* 2009; Cozzi *et al.,* 2013). The cost of electric fence use was addressed by all stakeholder groups. Some considered electric fence use worthwhile in the long-term, however, others (particularly farmers), viewed electric fences as too expensive. Perception of electric fence use was consequently dependent on income, size of herd and size of area that farmers want to be protected.

The use of electric fences is known to disrupt the natural movement of wildlife (Hayward *et al.,* 2009) and cause mortalities of species including tortoises and pangolins (Pietersen, Mckechnie and Jansen, 2014; Lee *et al.,* 2021); such deaths were reported by a minority of participants from all stakeholder groups in this study. Concerns about the negative impacts of electric fences on other wildlife were raised primarily by conservationist stakeholders in the current study, although the use of fencing does have some support in the scientific literature (e.g., Packer *et al.,* 2013). Stakeholder groups may therefore differ in their opinion of the success of electric fences. As such, it appears that perception of success may depend on whether the wider ecological landscape is being considered, or whether success is solely focused on a reduction in livestock loss.

Herders

Herding was perceived by conservationists as one of the most successful interventions. In contrast, farmer perceptions of herding varied, with some reporting the intervention as unsuccessful. In the scientific literature, herding is widely reported as one of the best interventions for preventing livestock depredation, however, it is becoming increasingly rare and socially problematic (Khorozyan *et al.,* 2017). As a result, herding is not practiced in areas where the costs of labour do not offset the costs of livestock loss (Breitenmoser *et al.,* 2005). In South Africa, increases in minimum wages for farm labourers has led to the shrinkage of employment on farms and has arguably made it more difficult for farmers to allocate resources to protecting their livestock (Nattrass and Conradie, 2015). Here, labour costs also emerged as a key factor in whether herding was perceived as successful. Factors such as size of herd, cost of food and availability of natural food also contributed to whether the use of herders was considered a successful and cost-effective strategy for reducing livestock loss by farmers. Such findings reiterate that cost effectiveness is vital for farmers when determining the success of intervention strategies; even if considered successful by conservationists, methods will not be utilised if not cost effective (Weise *et al.,* 2018). Furthermore, farmers perceived livestock to be most at risk from predation at night, and subsequently herding (which is not typically employed overnight) may not have been considered effective in reducing overnight livestock losses. Rather, farmers in this study preferred to invest in other interventions to protect livestock at night.

Lethal Control

Legislation regarding management and control of predators in South Africa varies between provinces (Diemont, Glazewski and Monaledi, 2018). In the Limpopo province, the hunting of carnivore species is permitted as long as the necessary permit(s) are in place and the activity remains in line with all other regulations and limitations (see Limpopo Environmental Management Act, 2004 (SA Gov, 2004)). However, the use of methods such as snares, cage traps and gin traps are not permitted. In addition, Threatened or Protected Species (TOPS) Regulations apply to listed threatened or protected species (cheetah, spotted hyena, brown hyena, African wild dog, lion and leopard). The TOPS regulations prohibit hunting threatened and protected species using methods such as dogs, poison, snares, traps baits and vehicles. However, TOPS regulations do not apply to threated or protected species that are damage-causing animals; regulations state that threatened or protected species can be deemed as damage causing if there is substantial proof of livestock loss, excessive damage to crops, trees or property or threat human life. Whether an animal can be described as a damage causing animal must be determined by provincial authorities. However, the regulations and definitions of problem species vary from province to province (Diemont, Glazewski and Monaledi, 2018). If approved, a permit can be issued to allow the hunting of problem animals. Despite the regulations, it is argued that outdated and conflicting legislation has exacerbated the frustration of livestock farmers confronted by livestock predation and, as a result, farmers often take matters into their own hands (Diemont, Glazewski and Monaledi, 2018).

Half of the farmers (n=10) in this study perceived the use of lethal control methods including shooting, poisoning and trapping, as successful. Lethal methods were considered successful because they produced quick and easy results in regard to removal of the perceived problem carnivore. It emerged that lethal control methods were most likely to be used as a reactive strategy in response to livestock loss, rather than as a preventative intervention. It was suggested by NGO and PAA stakeholders that farmers may continue using lethal methods to avoid the cost of investing in or maintaining other intervention strategies. Similar perceptions have been noted in other studies, for example, a study in the USA found that lethal carnivore control methods are still viewed as more effective and cheaper than alternative methods (Scasta, Stam and Windh, 2017).

In contrast, other participants suggested that retaliatory or preventative carnivore killing would not solve livestock loss and could cause other issues such as meso-predator release (Green *et al.,* 2018). Furthermore, it was felt by participants from all stakeholder groups that the younger generations were less likely to use lethal control. This parallels with previous findings that suggest lethal control was historically the main type of intervention strategy used but is no longer seen as the predominant form of livestock protection (Inskip and Zimmermann, 2009). In spite of this, the use of methods such as poisoning may continue if perceptions of the risks associated with this practice do not change (Brink *et al.,* 2021). In this case, from a conservation viewpoint, intervention use would need to incorporate the consequences to the wider environment, rather than focus solely on eradication of the perceived problem, in order for it to be environmentally sustainable. However, such environmental consequences were not salient concerns for the majority of participants in the current study and would therefore require dissemination to facilitate the use of landscape level measures of success.

All participants were aware that use of lethal control methods without appropriate permits were illegal in Limpopo province. However, lethal control was considered an easier option than using legal systems to apply for permits to hunt damage causing animals and dealing with the authorities for assistance in removal of problem animals. Farmers were therefore not purposefully trying to avoid the law but considered abiding by the law difficult and time consuming. This was also reflected by one NGO participant who felt that lethal control is still widespread and largely conducted in secret, subsequently making the true extent of such methods very difficult to determine. Given that it was considered easy to hide lethal control, farmers may therefore feel it unnecessary to engage with wildlife authorities and/or conservationists to report damage-causing animals. Consequently, improving relationships between stakeholder groups may help to better understand use of lethal control methods. In addition, since farmers in this current study regarded the legal system as inefficient, improving the functionality of the legal system and farmers engagement with the process may help to improve recording systems for damage-causing animal incidents and outcomes, allowing authorities to make more informed decisions around protecting both farmer and wildlife interests.

3B.4.2 Inter-stakeholder variation in perceptions of different HCC interventions

Perceptions of specific interventions were very personal; variation in perceived success was seen within and between stakeholder groups. Similarly, previous studies have suggested that the value of using interventions will vary between people and stakeholder groups due to differences in the believed effectiveness and feasibility of interventions (Eklund, Johansson, *et al.,* 2020). Intervention success is therefore likely to depend on what is best for the individual farmer and their current situation (e.g., funds available, livestock type and herd size). Furthermore, the environment in which strategies are utilised is not static and the perceived success of different interventions may change over time, exemplified by past experiences shaping perception. Despite this, there was agreement that no intervention is likely to ever be completely successful, but utilising multiple strategies will contribute towards reducing livestock losses. For example:

"*I have never worked with the Anatolians, but I've only heard how they do work but it doesn't, it's obviously not a 100% full proof."* N01

"*Ja you can never predict that these, these boma's that one builds is 100% er resistant erm, there's always a, you know there's always an offset chance that something happens you know."* N08

Most notably, there was a large difference in the perceived success of herding. Conservationists were more positive about the success of using herders in comparison with farmers. NGO stakeholders reported herding to be successful due to human presence deterring predators and the ability to monitor livestock constantly. Furthermore, it was thought that herders reporting incidents to farmers would enable them to keep track of any possible predation events. In contrast, increasing labour costs and the need to pay overtime at the weekend prevented some farmers from using herders, even if they had used them previously. One conservationist mentioned that the use of herders also had the benefit of job creation. However, given that some farmers regarded labour costs as high, it is unlikely that these farmers would share this perception. Whilst conservationists regarded the use of herders as a successful intervention, it emerged that farmers considered it more of a management practise in terms of being able to monitor where stock were and preventing issues with neighbours, rather than a strategy to reduce predation. Discussion with farmers on the use of herders predominantly arose when discussing livestock practises, rather than intervention use. This may suggest that more farmers in the study used herders but do not consider them an intervention strategy for mitigating depredation. A number of husbandry practices have been advocated as being beneficial for livestock protection for example, synchronized breeding, selection of certain breeds of stock (more aggressive or defensive of their young) and altering of herd composition (du Plessis *et al.,* 2018). This raises questions as to when a strategy becomes viewed as an HCC intervention rather than just a husbandry practise, exploring this further may help to differentiate perceptions of husbandry practices versus intervention strategies, and where functional overlap may occur. This will be important to explore further, given that for the majority of farmers successful strategies focused on managing carnivore presence and/or behaviour rather than managing livestock.

Conservationists reported that kraaling of livestock was likely to be the most popular method amongst farmers. However, not all farmers thought that kraaling was successful, particularly for cattle. Thereby revealing another area of inter-stakeholder difference. The type of fence used (electric or non-electric) also impacted perception of success with kraals. The effectiveness of electrified fences has previously been found to be highly dependent on maintenance (Kesch, Bauer and Loveridge, 2015). In this study, fence maintenance was viewed as vital to fence success by participants from all stakeholder groups, for example:

"*The first thing I will always tell a farmer when he complains, I said are you looking after your fences?"* N06

However, such comments also suggest that whilst stakeholders agreed that fence maintenance is necessary for success, whether this is implemented on the ground by users is likely to vary. A previous study noted many reasons as to why kraals were not used consistently and included owners being occupied with other tasks and the lack of necessary maintenance (Weise *et al.,* 2018). This highlights the importance of understanding stakeholder involvement and responsibility in achieving success.

3B.5 Conclusions

Given the varied perceptions of different interventions revealed here, it is unlikely that any single approach aimed at increasing HCC is universally applicable or successful. Moreover, interventions considered successful for a particular species or problem may be unlikely to succeed if transferred to disparate contexts (Loveridge, Kuiper, *et al.,* 2017; Mkonyi *et al.,* 2017; Khorozyan, 2020; Zimmermann *et al.,* 2021). This study shows that several factors shape people's perceptions of specific intervention strategies. As such, intervention success needs to be evaluated using multiple criteria including cost-efficiency, social acceptance and environmental consequences (e.g., use of fences, LGDs, and lethal methods) (Ohrens, Santiago-Ávila and Treves, 2019).

Strategy success was shaped by past experiences as well as aspects of their current situation including herd type and size. Night-time was considered the most important time of day to utilise intervention strategies and this likely contributed to the difference between stakeholder groups in the perceived success and use of herding. Overall, financial considerations and cost-effectiveness emerged as the most important factors driving intervention use and perceived success. For strategies to be considered successful by farmers, they must be financially viable. Costs should therefore be transparently discussed prior to strategy implementation. In the current study, lethal control methods were viewed as inexpensive and easy to use; if non-lethal methods are shown and accepted to be less expensive (both in the short and long-term), use of lethal control methods may reduce. Facilitating a comparison of the costs of lethal and non-lethal methods, and ensuring dissemination of findings to end-users, would enable farmers to make informed decisions about intervention costs with the aim of reducing the use of lethal control methods and achieving HCC goals.

Using a combination of strategies (e.g., a kraal and LGD together) was perceived as the most successful and therefore held the greatest potential for increasing HCC. This approach to depredation mitigation was often explained as most successful due to its ability to not only reduce the risk of livestock predation but also protect against theft, a key concern for farmers in the study. Having a combination of strategies gave farmers reassurance that if there was a problem with one strategy, there was a backup in place and livestock were still protected from predation. For example, the kraaling of LGDs at night was considered a way to protect livestock and alleviate concerns about theft/injury to LGDs so dogs could continue working effectively during the day. Understanding which strategies stakeholders perceive as successful, as well as the factors that contribute to perceived success, will facilitate a more informed decision-making process when implementing interventions. The findings from this study can be used by conservationists and those implementing interventions to understand which strategies may be accepted by users as well as concerns that should be addressed prior to implementation.

Chapter 4: Similarities and differences between interview and camera trap data in exploring livestock-carnivore interactions.

4.1 Introduction

For many stakeholders, conservation is not just about measuring changes in biodiversity and increasing populations, it is a social process that requires the involvement of human communities (Malmer *et al.,* 2020). Failing to consider and manage the impacts of conservation processes on humans has often undermined the ethical standing and effectiveness of conservation actions (Gavin *et al.,* 2018). Acknowledgement of the need for conservation initiatives to consider the social aspects of scenarios including understanding people's perceptions and behaviour towards focal species is not new (e.g., Dickman, 2010), but only recently have studies on stakeholder perceptions gained substantial relevance in conservation biology (Bennett, 2016). Studies which improve the understanding of the relationship between humans and wildlife subsequently enable implementation of conservation interventions that are more effective (Messmer, 2009; Bennett *et al.,* 2017). Moreover, the inclusion of multiple stakeholders and use of different knowledge sources can strengthen the legitimacy of decision-making and implementation (Malmer *et al.,* 2020). Recognising the value of all sources of knowledge and using evidence from multiple sources may subsequently be beneficial in understanding human-carnivore coexistence (HCC) scenarios and, in particular, livestock-carnivore interactions.

Knowledge systems include the practices, structures, mindsets, values, cultures, and institutions affecting what and how knowledge is produced and used, and by whom (Fazey *et al.,* 2020). Historically, conservation initiatives have been guided by scientific knowledge. The term scientific knowledge is used to describe the information typically generated by researchers from universities and research institutions using experiments and empirical observations (Leach, 2007; Díaz *et al.,* 2015). Generation of scientific ecological knowledge tends to be driven by theoretical models and hypothesis testing using data collected via the scientific method. Scientific observations (often, but not always, co-ordinated by small groups of professionals), tend to be quantitative and often represent simultaneous observations from a wide range of sites (Kimmerer, 2002; Gandiwa, 2012). The techniques used to generate expert-based science can be expensive and demanding of resources (Anadón *et al.,* 2009). However, in practice, not all scientific knowledge is applicable to local communities as it does not regularly take into consideration local needs and knowledge (McDougall and Braun, 2013) and may be regarded as culturally blind (Rudd *et al.,* 2021). Yet, it is recognised that scientists have tended to dominate the design and implementation of collaborations across knowledge systems both historically and contemporarily (Mistry and Berardi, 2016). To date, most understanding of livestock-carnivore interactions and carnivore conservation initiatives has been based on knowledge derived externally to local communities, drawing from a variety of sampling methods including track surveys, telemetry, call-ins and camera traps.

Camera traps were developed in the 1980s and their use in the biological sciences has grown rapidly since 2002 (Apps and McNutt, 2018). During this time, camera traps have contributed to science through providing data to enable researchers to investigate parameters such as species identification, distribution, density, demography, behaviour and community composition (Klailova *et al.,* 2013; Burton *et al.,* 2015; Agha *et al.,* 2018). Camera traps are popular due to their versatility, low effort-to-data volume ratio and ability to cost-effectively monitor multiple species and even detect some rare, cryptic and elusive animals (Burton *et al.,* 2015; Rowcliffe, 2017). Camera trapping also provides a minimally invasive means of surveying wildlife (Caravaggi *et al.,* 2017; Agha *et al.,* 2018) and their use allows for continuous data collection.

Using camera traps to collect presence-absence data is cost-effective and enables surveys to be implemented across wide areas (Andresen, Everatt and Somers, 2014). Such surveys facilitate occupancy modelling to estimate detection probabilities and provide an index of abundance (Burton *et al.,* 2015). Multi-species occupancy models (MSOMs) can also be used to measure species richness and species-specific effects of occupancy and habitat use (van der Weyde, Mbisana and Klein, 2018). However, non-detection in presence surveys does not necessarily mean that a particular species is absent from the area (Burton *et al.,* 2015). Likewise, although widely used, mark capture-recapture models do not work for species that cannot be identified individually e.g., black-backed jackal (*Canis mesomelas*). To overcome this limitation, the random encounter model (REM) was developed to permit density estimates of species that cannot be individually identified (Rowcliffe *et al.,* 2008). However, careful attention needs to be paid to camera trap placement, effort and grid pattern in order to optimise data quality and suitability for modelling (see Kays *et al.,* 2020). The inability to identify individuals is a limitation common to the majority of species surveyed in camera traps studies and has likely led to an increase in the use of occupancy modelling or indexes of abundance (Burton *et al.,* 2015; Steenweg *et al.,* 2019; Delisle *et al.,* 2021). Open-source software for the organisation and analysis of camera trap data e.g., R packages “camtrapR” (Niedballa *et al.,* 2016) and “activity” (Rowcliffe *et al.,* 2014; Rowcliffe, 2019), has also provided a more accessible means of testing sophisticated hypotheses (Delisle *et al.,* 2021).

Despite their popularity, there are a number of constraints to the use of camera traps, including set-up costs, theft and vandalism, poor performance in extreme environments, camera-sensor performance, battery life and damage by wildlife (Burton *et al.,* 2015; Glover-Kapfer, Soto-Navarro and Wearn, 2019; Meek *et al.,* 2019). A global survey of researchers using camera traps identified improved sensors, faster triggers, extended battery life, and protection from temperature, humidity and theft as key development priorities for camera trap use (Glover-Kapfer, Soto-Navarro and Wearn, 2019). These factors may be acting as significant constraints on the effective application of the technology to meet research and survey objectives. It is suggested that many of these constraints arise because wildlife researchers represent a secondary market for camera trap manufacturers with most catering primarily to the recreational hunter (Ahumada *et al.,* 2020). However, there is limited published literature on the use of camera traps outside of academia and scientific research.

There are also methodological constraints to camera trap surveys. For example, differences in statistical power and spatial mismatches in data obtained from camera trap versus GPS-collar sampling have been hypothesised as explaining differences in findings for wildlife-habitat relationships (Bassing *et al.,* 2022). Camera traps may disproportionately sample certain behaviours, especially when used for rare or elusive species such as carnivores, although have the benefit of generating a more random sample of the population than GPS-collar sampling (as reviewed in Bassing *et al.,* 2022). Likewise, inter-observer variation may be an important confounder in camera trap studies, whereby recent research has revealed significant differences in image processing time, species detection rate and species identification accuracy (Zett, Stratford and Weise, 2022). Observer experience and other observer-related variables, as well as the species distinctiveness and camera location were all important sources of potential error, and raised concerns regarding the reliability of camera trap data for use in studies of wildlife populations or biodiversity (Zett, Stratford and Weise, 2022). Nonetheless, camera traps have recently been used in research with conservation benefits; for example, through their use in investigations of the impact of anthropogenic changes on animal behaviour (Berger-Tal *et al.,* 2011; Oriol-Cotterill *et al.,* 2015). Furthermore, camera traps have been used to monitor wildlife responses to conservation interventions (e.g., human-wildlife interaction mitigation strategies), including camera trap studies demonstrating the effectiveness of bees in reducing crop foraging by elephants (Ngama *et al.,* 2016; Caravaggi *et al.,* 2017). In the last decade, the use of camera traps to conduct studies of species overlap has gained popularity (e.g., O'Brien, Kinnaird and Wibisono, 2003; Linkie and Ridout, 2011; Havmøller *et al.,* 2020).

Scientific knowledge is not the only system in which conservation knowledge can be generated. Alongside the production of scientific knowledge, people residing in areas for long periods of time develop relationships with and knowledge about those areas (Prado and Murrieta, 2015). Various terminologies have been proposed to describe this knowledge including, local ecological knowledge (LEK) (Anadón *et al.,* 2009), traditional ecological knowledge (TEK) (Phuthego and Chanda, 2004) and indigenous local knowledge (ILK) (Roba and Oba, 2009). Local ecological knowledge (LEK- the term adopted hereafter) is increasingly being utilised by academics, scientists, and policymakers as a potential source of ideas for conservation initiatives (Gandiwa, 2012). Additionally, harnessing LEK can be an efficient, accurate tool for detecting the presence of large terrestrial mammals (Camino *et al.,* 2020).

Local ecological knowledge tends to be qualitative and generated over time through interactions and experience with the landscape. The observers are usually the resource users themselves and include people such as hunters, farmers, fishers, and gatherers whose livelihoods are inextricably linked to the quality and reliability of their ecological observations (Gandiwa, 2012). A number of methods can be used to obtain and understand LEK e.g., participatory maps, participatory planning, film, ethnography and semi-structured interviews (Malmer *et al.,* 2020). Interviews are widely used in the social sciences and are a common method of collecting LEK through asking people about the landscape in which they interact with daily (Huntington, 2000). Interviews can also be used to obtain information on local perspectives of wildlife ecology and conservation (Caruso *et al.,* 2017). In contrast to resource intensive methods such as camera trapping, harnessing LEK represents a relatively quick and cost-efficient method of collecting data on species presence over large, or remote areas.

In the last decade the use of LEK in conservation and ecology research has expanded, and it has been used for a number of purposes. For example, LEK has been used to determine species distribution at local and national scales (Riggio and Caro, 2017; Madsen *et al.,* 2020), as well as species occurrence (Nguyen *et al.,* 2019) and habitat use (Madsen *et al.,* 2020). Such studies have confirmed that local people are adept at recognising and distinguishing different animal species, as well as noticing and explaining qualitative population trends (e.g., Gandiwa, 2012). However, many studies using LEK at the species level have focused on relatively highly abundant and easily detectable species, and/or species with significant socio-economic or cultural importance. Less research has used or investigated the use of LEK in relation to scarce, cryptic, elusive or nocturnal species (Torrents-Ticó *et al.,* 2021).

As with any knowledge source, there are recognised constraints to LEK and it should be acknowledged that LEK can provide inaccurate or incomplete information (e.g., Daw, Robinson and Graham, 2011). As such, data obtained by interviewing local inhabitants should be used with caution as information about species presence may be inaccurate and/or biased (Caruso *et al.,* 2017). For example, interview data may be biased towards species that cause problems rather than rare, shy or unproblematic species as local people tend to have greater knowledge (likely related to experience) of problem species (Caruso *et al.,* 2017). Variance within social surveys is complex and interview bias has long been recognized (Moser, 1951). Retrospective bias appears to be a commonly reported phenomenon in LEK studies (Rafferty, Walthery and King-Hale, 2015). For example, Bessesen and Gonzalez-Suarez (2021) note that respondents tended to over-estimate perceived abundance. Furthermore, LEK studies with relatively few respondents can limit researchers' ability to identify all the factors that shaped respondent perceptions (Davis and Wagner, 2003). Furthermore, varying levels of expertise and differing experiences can influence people's responses (Joa, Winkel and Primmer, 2018; Bessesen and González-Suárez, 2021). Due to these limitations, LEK methods can be criticised by scientists for being used without evaluation or standardisation whilst knowing that people's perceptions, subjectivities and experiences may bias results (Joa, Winkel and Primmer, 2018).

It follows that, despite acknowledgement of the need and benefit of engaging with local communities, they are often included as stakeholders in conservation without recognition of their knowledge and expertise (Malmer *et al.,* 2020), i.e., as passive end-users without input. Many papers discuss the need for open participation and consultation with stakeholders, rather than addressing their role as knowledge holders (Malmer *et al.,* 2020). Studies rarely link LEK to scientific knowledge, and when they do, LEK reliability is assessed according to or in comparison to scientific knowledge (e.g., Gandiwa, 2012; Caruso *et al.,* 2017; Ballejo, Plaza and Lambertucci, 2020). As such, there is still a tendency to validate LEK with scientific knowledge (Torrents-Ticó *et al.,* 2021). As an example, Nguyen *et al.,* (2019) firstly used interview surveys to obtain information on the occurrence of silver-backed chevrotains in Nha Trang, Vietnam, and then conducted opportunistic camera-trapping in areas which were determined as most-promising from the interviews. The presence of the species in question was not officially validated by researchers until camera trap images had been recorded. Another study by Ballejo, Plaza and Lambertucci (2020) compared observation and perception data for scavenger birds in Argentina and found that researchers' field observations did not support local people's perceptions with an inferred assumption that researcher observations were more reliable. Such external validations could be seen to dismiss the validity and use of LEK, and subsequently disempower LEK holders. Therefore, in practice, there exists scepticism about the effectiveness of LEK as evidence in conservation. However, LEK should not be benchmarked against data generated by external researchers since all knowledge systems have strengths and limitations (Johnson *et al.,* 2016). Similarly, holders of LEK can be wary of the claims generated through scientific approaches due to both their unfamiliarity with the methods employed and their experiences of disempowerment (Malmer *et al.,* 2020). Additionally, if camera traps do not detect species known by people to be there, it is unlikely that they will trust the results generated by such scientific approaches.

However, LEK and scientific knowledge are not necessarily mutually exclusive (Díaz *et al.,* 2015), and there are a variety of approaches used to integrate knowledge systems (Raymond *et al.,* 2010). A few studies have looked at the two knowledge systems as complementary which not only helps to understand abundances and trends, but also helps to recognise conservation needs and challenges. For example, the Lion Guardians project, Kenya, demonstrates how complementing scientific monitoring with LEK can help to monitor lion movements in a participatory way (Dolrenry, Hazzah and Frank, 2016). Through three case studies, Malmer *et al.,* (2020) demonstrates synergies between LEK and conservation science, and how the use of mixed method approaches can lead to stronger partnerships and better outcomes. Morales-Reyes *et al.,* (2019) found high consistency between local and scientific knowledge regarding the provision of the scavenging by vertebrates. Recently, Torrents-Tico *et al.,* (2021) complemented proxies of abundances and trends of carnivore species derived from common scientific sampling methods and semi-structured interviews among a pastoralist community from northern Kenya to reveal how convergences and divergences between knowledge sources can be used to inform carnivore conservation. These studies demonstrate how complementing different knowledge systems can be used to generate useful and valuable knowledge for better understanding HCC and achieving conservation goals.

Moreover, there is increasing recognition that complementing different knowledge systems is key to widening the evidence underpinning conservation initiatives (Torrents-Ticó *et al.,* 2021). It has been suggested that LEK and scientific knowledge should be used as complementary frameworks that enable collaborations between knowledge systems (Whyte, Brewer and Johnson, 2016; Kutz and Tomaselli, 2019). Use of multiple knowledge systems can extend knowledge and contribute to better understanding conservation issues (Malmer *et al.,* 2020). The use of multiple sources of evidence has many potential positive outcomes including emergence of novel factors, development of more efficient responses and better implementation of findings (Malmer *et al.,* 2020). Furthermore, the integration of different knowledge systems is necessary when a single knowledge system fails to sustainably manage, or fully understand issues (Nguyen, Luom and Parnell, 2017), such as human-carnivore interactions.

In this study, we were interested in complementing scientific knowledge and LEK using a qualitative exploration of convergences and divergences between the two different knowledge systems to deepen the understanding of human-carnivore interaction scenarios and in particular livestock-carnivore interactions. Here, scientific knowledge refers to information obtained from camera traps and LEK refers to perceptions of local stakeholders gathered through interview data. For the purpose of this study, livestock is defined as domesticated animals managed for commercial purposes or human benefit in circumstances that may render them vulnerable to depredation (Kerley, Wilson and Balfour, 2018). Camera traps were placed in areas identified by participants as being livestock-carnivore interaction hotspots (i.e., LEK was used to inform camera location), whilst farmer perceptions of visits and interactions were obtained from interview data. The study focused on carnivore species that were mentioned in interviews as being the most likely to cause livestock predation (see chapter 2). The purpose of using both these datasets was not to validate one set of observations over the other, but to complement information collected at different spatial and temporal scales and identify potential mechanisms to explain both sets of observations (Huntington, Suydam and Rosenberg, 2004). Studying the interactions between carnivores and livestock can be challenging in part due to carnivores' cryptic behaviour and low abundance (Ripple *et al.,* 2014). Yet understanding how carnivores and livestock interact, and the perceptions of these interactions, is vital when considering HCC and methods aimed at increasing or facilitating this. Using both camera trap and interview data therefore provides further insight into perceptions of livestock-carnivore interactions and their implications for coexistence. Furthermore, this approach allowed for reflections on the use of different methods to obtain information and how this information can be used or interpreted by stakeholders, including researchers.

This study aimed to:

- Assess the similarities and differences between LEK and camera trap data regarding the presence of carnivores, frequency of visits and livestock-carnivore interactions.
- Identify and discuss how camera trap and LEK data can be used in HCC scenarios, and to understand livestock-carnivore interactions.

4.2 Methods

4.2.1 Ethical Considerations

The project was approved by the Nottingham Trent University School of Animal, Rural and Environmental Sciences Ethical Review Group (ARE845 and ARE880). Upon meeting with the participants, the project was explained, including relevant ethical considerations. It was made clear that all responses were voluntary and confidential, and that all data would be anonymised and stored securely. For full details of interview ethical considerations see chapter 2.2.2. The camera trap survey was solely observational and non-invasive therefore causing minimal disturbance to wildlife, livestock or the environment.

4.2.2 Camera trap knowledge

Camera trap method development

A pilot study was conducted to aid in developing a methodology for the main study, assessing the feasibility of asking participants to identify potential livestock-carnivore interaction hotspots, and subsequently using these locations to determine recorded carnivore visits. The location for the pilot study was selected due to the combination of it being a livestock farm with two popular methods of livestock protection (a livestock guardian dog (LGD) and electric fenced kraal), and its hosting of the Alldays Wildlife and Communities Research Centre (AWCRC) where the researcher was based. As such the location was both accessible and the livestock owner willing to participate in the project. Initially, four Browning Strike Force HD Pro X (Model BTC-5HDPX) camera traps were positioned around the perimeter of the kraal at locations chosen by the farmer based on previous carnivore experiences. For example, they had previously seen carnivore tracks close to the kraal gate and so wanted to put a camera there. Consequently, one camera was placed close to each gate and the other two on trees approximately five to ten meters from the kraal fence. All cameras faced along the fence of the kraal and covered a well-used road that covered the perimeter of the kraal.

Cameras were set to operate for 24 hours a day; 30s and 1s capture delay were trialled and a 30s delay was determined sufficient to capture all carnivore visits whilst minimising unnecessary captures of non-target species (e.g., livestock). To ensure maximum detections, camera traps should be placed just below the height of the target animals' shoulder height and aimed level with the ground (Apps and McNutt, 2018). As the study aimed to capture multiple species (with typical shoulder heights ranging from 35-50cm for black backed jackal to 70-80cm for brown hyena), a height of 60cm and angle of 90° were deemed appropriate (van der Weyde, Mbisana and Klein, 2018), aligning with other multi-species studies (Stein *et al.,* 2011; Abade *et al.,* 2018).

Secondly, the use of paired camera trap stations was tested; two cameras were placed in each location facing opposite directions or at 90° to each other, depending on the location. This method was tested to assess whether it affected the number and frequency of recorded, independent carnivore visits.

Camera trap data extraction and analysis

Photos from the pilot were sorted and images tagged when they included species of interest using DigiKam (v 6.3). Species of interest were carnivore species named in the interviews as damage causing (black backed jackal, caracal, brown hyena and leopard) and species relating to farm activity (humans, livestock, domestic animals and vehicles). Each species (including humans) and any vehicles present in images were tagged, shadows were not tagged even if the species was identifiable. Livestock species were also tagged and comprised cattle, goat, sheep and horses. Any mode of farm transport e.g., quad bike, tractor and car were tagged as a vehicle. For images including both a vehicle and person, and where the person had one or more feet touching the ground 'vehicle' and 'person' were tagged separately. The species tag 'person' was further divided to include tags of farmer, workers, researchers and unknown. Tagging of 'person' in this way enabled images of people to be used and later filtered out to be stored securely in line with safe-guarding practises.

All metadata from each image were then exported using Exiftool to include: date, time, species and number of individuals. The definition of a visit followed previous authors' definition of an independent visit (O'Brien, Kinnaird and Wibisono, 2003; Ridout and Linkie, 2008) whereby an independent visit was distinguished by: consecutive records of different species, non-consecutive records of the same species and consecutive records of individuals of the same species taken more than 30 minutes apart. The number of individuals per visit was recorded, however, multiple individuals of the same species recorded in the same photo were counted as one visit. Different species recorded at the same time were counted as separate visits. Identification of individuals for any species was considered beyond the scope of the study. Data were extracted to investigate species present, number of visits per species, and time of visits.

Visits by brown hyena (*Hyaena brunnea*), and black backed jackal were recorded in the pilot study. A comparison of the number of visits recorded with single and double stations determined that one camera trap per station was sufficient to record carnivore presence at the locations identified by participants as being interaction hotspots.

Camera trap main study

This chapter utilises participants from semi-structured interviews. The participant recruitment and interview methodology process are detailed in chapter 2.2.

Participatory mapping to determine camera placement

To identify livestock-carnivore interaction hotspots, participatory mapping was carried out as part of the interview process with livestock farmers. Prior to the interview, a map of the farm was obtained from Google Maps and saved to a tablet (Samsung Galaxy Tab A). Multiple screenshots were taken to ensure the farm was fully covered and images from different scales were taken. Farmers were shown the map during the interview and were asked to draw onto the map the farm boundaries using the photo edit mode. Following this they were asked to identify areas where they perceived carnivores to occupy and move, areas where livestock and carnivores were most likely to interact, and any landscape features they felt were important, for example, water sources and koppies (small rocky outcrops). Different colours were used to identify different features, whilst lines and marks could also be deleted and redrawn if necessary (Figure 4.1).

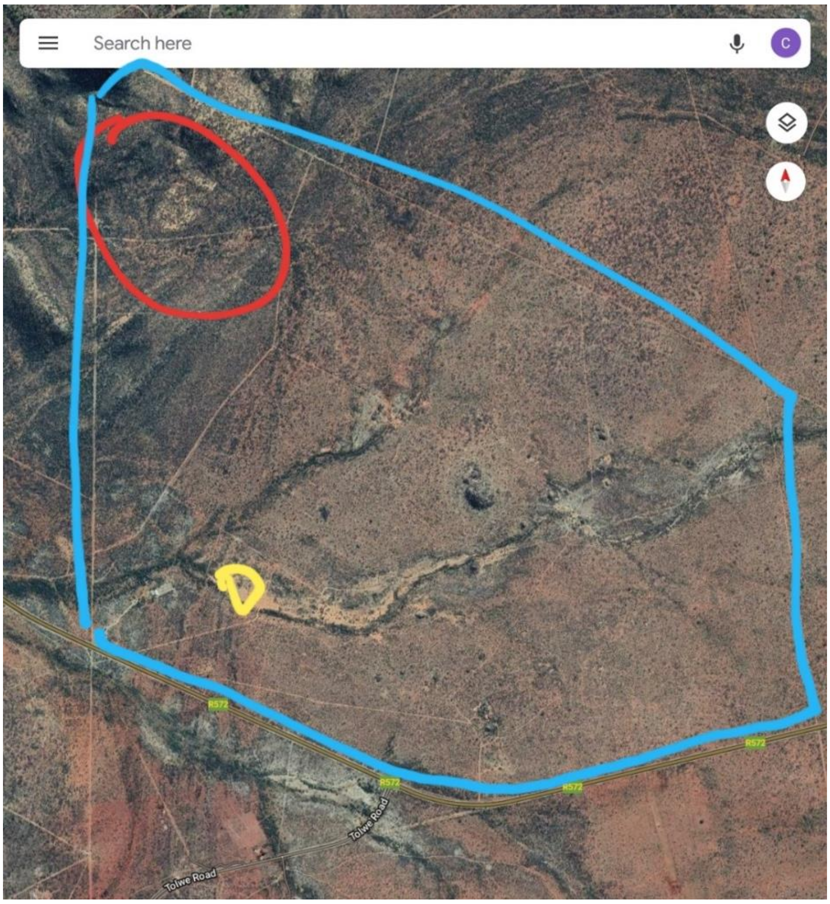

Figure 4.1: Carnivore-livestock interaction hotspot areas were identified through participatory mapping whereby farmers were asked to draw on maps of their property. Here, the blue line represents the farm boundary, yellow shows the location of the livestock kraal and red the area of the farm where carnivores were thought to occupy.

Participatory maps were completed in 12/20 farmer interviews. In instances where participants were recruited via snowball sampling and subsequently interviewed immediately after the nominating participant without preparation time, it was not always possible to prepare a map for use at interview (e.g., due to a lack of mobile signal and/or internet access at the interview site). In these instances, participatory mapping was not conducted and if the participant agreed to camera trapping on their property, placement was determined in the field whereby the farmer accompanied the researcher to set the cameras up and helped to select the most appropriate locations. Participatory mapping was not conducted where participants did not consent to camera trapping on their property.

Camera trap deployment

A total of 53 camera traps were deployed at 12 survey sites on 11 farms between September 2019-May 2020 (Figure 4.2). Selection of farms for camera trap surveying was based on farmer willingness to participate in the project. Two locations were used on one farm as the owner rotated use of cattle kraals and asked for cameras to be placed in both locations at different times, according to herd movements. In addition, two farm locations were represented by one farmer- they owned one farm and rented another property to enable ownership of more livestock. Between 3 and 7 cameras (a mixture of Browning Strike Force HD Pro X-BTC-5HDPX, Bushnell Trophy Cam- 119837C and Moultrie Trail Cam- MFH-DGS-M80/ MCG-12594 M-880) were placed on each farm subject to the number of interaction hotspots identified. From July- November 2019 the project only had access to the Browning and Moultrie camera traps; the Bushnell cameras were made available from November 2019. Therefore prior to November 2019 only a single brand was used per farm. All camera trap models used infrared flash, but flash range varied between the models (Browning = average 24.4m, Bushnell = 12- 30m and Moultrie = 10.7-13.7m). Trigger speed ranged from 0.22 sec (Browning) to 0.3 sec (Bushnell).

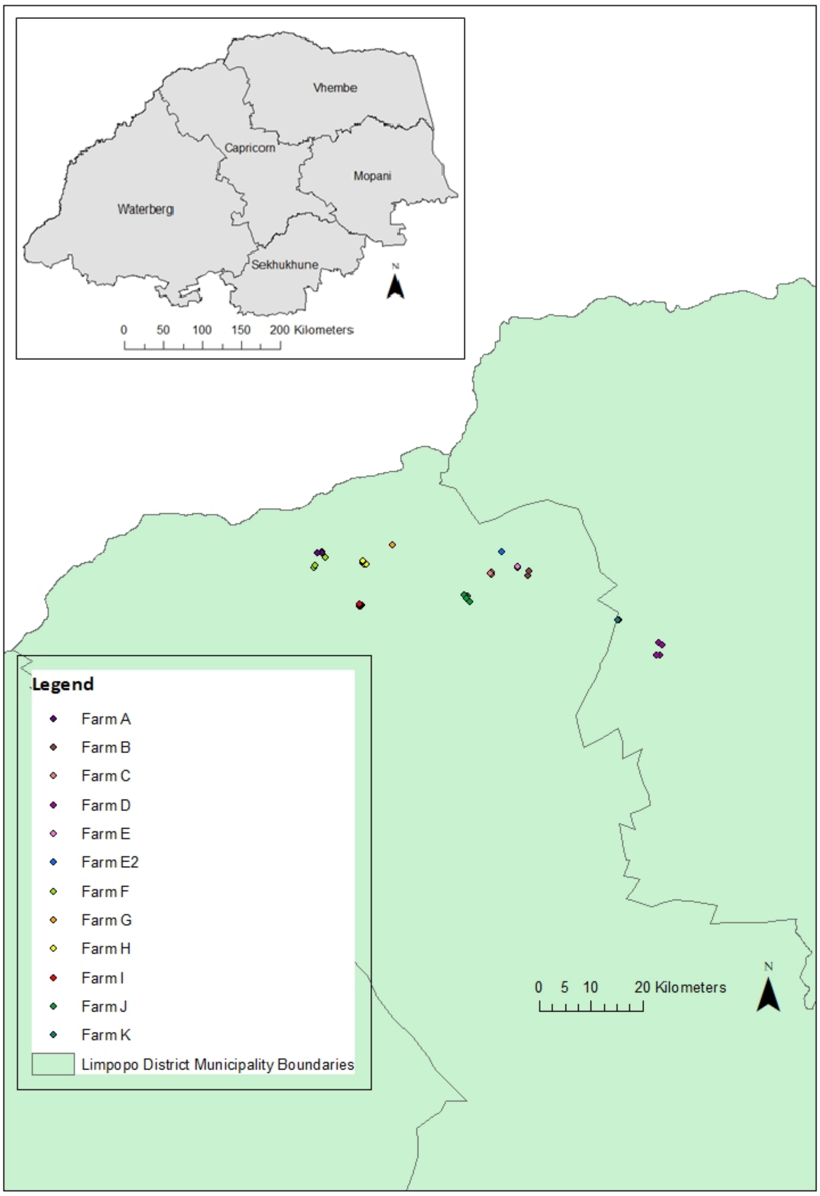

Figure 4.2: Locations of all camera trap locations within the Capricorn and Vhembe districts. Inset map shows the locations of the Capricorn and Vhembe districts with the Limpopo Province, South Africa.

Camera trap placement was determined by farmer knowledge and identification of livestock-carnivore interaction hotspots as well as practical considerations such as vegetation obstruction, equipment security, access, and environmental factors such as the direction of sunrise/sunset. As determined to be appropriate in the pilot study, cameras were mounted on trees or posts approximately 60 cm above the ground, angled at 90° to the ground and set to operate for 24 hours a day with 30s capture delay. Cameras at kraals were positioned to record the kraal fence and therefore record movement inside and outside the kraal but coverage of the entire kraal perimeter (as in the pilot study) was not feasible given the number of cameras available. Cameras were serviced regularly (approximately every 14 days, depending on ease of access to the farm) to download images, check batteries and ensure they remained operational in accordance with camera trap best practices (Henschel and Ray, 2003). It should be noted that camera traps were out in the field when South Africa went into national lockdown due to the global Covid-19 pandemic in March 2020. The researcher had to leave South Africa and cameras were left under the care of in-country partners until the study end. In-country partners in South Africa were able to service the camera traps and remove them. However, due to lockdown restrictions some data may have been lost due to SD cards filling up; 11/29 camera stations serviced during this period were found to have full SD cards at the time of servicing.

Camera trap data extraction and analysis

Sampling effort was calculated as sum of the total number of camera traps multiplied by the number of effective days of sampling. Camera trap image tagging was conducted as described for the pilot study. Tagging for the main study was initially completed by six assistants. All assistants were trained by the researcher and all image tags were subsequently checked for accuracy by the researcher in DigiKam.

Overlap analysis was conducted in R (v.4.1.2) using the “overlap” package (Meredith and Ridout, 2014); the statistical code for R (developed by Ridout and Linkie (2008)) was made available by Linkie and Ridout (2011) and includes a measure of precision of the estimated overlap in the form of confidence intervals. Overlap is defined as the area under the curve that is formed by taking the minimum of the two activity patterns at each time point (Linkie and Ridout, 2011); Coefficients of overlap (Δ) range from 0 (no overlap, for example, if one species is nocturnal and the other diurnal) to 1 (complete overlap and identical activity patterns). The most reliable estimator for sample sizes smaller than 50 is Δ_1 and for samples greater than 75 is Δ_4. This study had a farmer sample size of less than 50 and subsequently used Δ_1. All other samples were greater than 75 and therefore Δ_4 was used. 10,000 bootstrap samples were used to measure 95% bootstrap confidence intervals (Linkie and Ridout, 2011). To obtain the confidence interval the basic0 output from bootCI was used (Meredith and Ridout, 2014).

4.2.3 LEK knowledge

This chapter utilised data from semi-structured interviews. Details of methods are provided in chapter 2.2. This chapter used a form of content analysis to explore and interpret the interview data. Content analysis is “a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use” (Krippendorff, 2004, p. 18). Content analysis was deemed relevant to extract and explore specific data. As such, this study focused on knowledge generated from participant responses to the following subsection of interview questions:

Questions for farmer stakeholders:

- What predator species do you get on your property?
- Which predator species cause the most damage on your farm?
- How often do you think your livestock comes into contact with predator species?
- When do you think they (livestock and carnivores) are most likely to come into contact?
- Is there a particular type of livestock most likely to come into contact with predators?

Questions for conservation (protected area authority (PAA), non-governmental organisation (NGO) and tourism) stakeholders:

- Which species do you think farmers think cause the most damage?
- Which predator species do you think causes the most damage on farms in the area?
- How many times per month do you think livestock come into contact with predators?
- When do you think they (livestock and predators) are most likely to come into contact?
- Is there a particular type of livestock most likely to come into contact with predators?

The term predator was used as this was the term commonly used by participants to mean carnivore species. Responses to questions regarding carnivore-livestock interactions were analysed for all participants, regardless of their participation in the camera trap survey. Analyses of both LEK and camera trap data were restricted to those farms for which both knowledge sources were available.

Due to the semi-structured and inductive approach used in interviews, follow on questions may have been asked and participants may have responded to other questions with information relevant to this study. As such, other relevant statements and emergent themes were also drawn from the interviews. One such theme was farmer perception of camera trap use. The interview guide did not explicitly ask whether participants had camera traps on their property or their opinion on camera trap use. However, farmers involved in participatory mapping were asked if they utilised camera traps as part of this mapping process. Any instances where participants mentioned camera traps and their use was extracted from interview transcripts. All relevant information was extracted via coding using QSR NVivo v12 (http://www.qsrinternational.com) to draw out responses and themes relating to perceptions of livestock-carnivore interactions and camera trap use.

4.2.4 Concurrent assessment of knowledge sources

To enable discussion about similarities and differences between LEK and camera trap-derived knowledge of carnivore presence, data were first classified to categorise the LEK and camera trap on each property according to a common set of descriptors (absent, low, medium or high). Of the 12 camera locations, nine sites had both interview and camera trap data (Table 4.1). For the farms with both interview and camera trap data, LEK data for each carnivore species were then coded, based on summations of the responses, as: present, occasional and rare (Table 4.2). Carnivore species detected on camera traps were then classified for presence as: absent, low, medium, or high according to the percentage of detections of camera trap images determined to contain the species (Table 4.2). Detection rate was calculated by dividing the number of detections by the total number of camera trap nights (as per (Parsons *et al.,* 2017). Classifying the data in this way allowed for LEK and camera trap data to be evaluated on an approximately equivalent basis .

Table 4.1: Farm information and data available for each study farm.

Farm ID	Camera Trap Data	Interview Data	Farm Size (hectares)	Farm Boundary Type	Herd Type	Herd Size	Mitigation
Farm A	Yes	Yes	300	Game	Sheep, some cattle, some goats	60 sheep	Kraal, 3x LGD, near to house
Farm B	Yes	Yes*	800	Cattle fence	Cattle	30	Kraal
Farm C	Yes	Yes	1700	Game	Goats	213	Electric fence kraal, 1 LGD
Farm D	Yes	No	550	Game	Sheep, cattle	70 sheep, some cattle	Kraal, 2 LGD
Farm E	Yes	No	2400	Game fence	Cattle	45	Kraal
Farm E2	Yes	No	2400	Game fence	Cattle	45	Kraal
Farm F	Yes	Yes	856	Mixed game and cattle	Cattle	22	Cage Trap
Farm G	Yes	Yes	428	Game	Cattle	77	Kraal
Farm H	Yes	Yes	900	Electric game fence	Sheep, few cattle	60-70 sheep, 11 cattle	Kraal inside of crop fields, external fences= electric, internal=cattle
Farm I	Yes	Yes	3000	Game, some electrified	Sheep, few cattle	10 sheep, 12 cattle	Electric fence kraal
Farm J	Yes	Yes*	800	Game	Cattle, sheep	45 cattle, 20 sheep	Electric fence kraal
Farm K	Yes	Yes	1851	Game	Goats, sheep, cattle	1500 goats, 150 sheep, 200 cattle	Kraal, 5x LGD

***:** Farm B and J utilise the same interview data; the farmer owned J and rented B for other livestock. The farms did not neighbour each other.

Table 4.2: Classification of camera trap and interview data into equivalent categories.

Classification	% of detections (the number of detections divided by total number of trap nights)	Farmer-reported Carnivore Presence
Absent	0	None
Low	<10	Rare (seen in the past)
Medium	11-60	Occasional (passes through)
High	>61%	Present (always present)

Given the mixed methods approach used here and the strategy used to place camera traps, the results were not intended to be explored using inferential statistics and will be discussed qualitatively. As such, this study does not aim to prove one knowledge system as inferior to the other but brings into focus the importance of exploring different knowledge systems and acknowledging the similarities and differences between data generated from different knowledge sources. Herein we explored potential reasons for these similarities and differences, and the implications for HCC scenarios.

4.3 Results

4.3.1. Camera trap detections

Total sampling effort was 1821 trap nights (Table 4.3). Sampling days were lost due to camera malfunction or movement of the camera by livestock and/or wildlife. No camera traps were lost to theft or wildlife damage. In total there were 493 independent records of carnivore activity.

Table 4.3: Locations of camera trap surveys with camera deployment dates, camera brands, locations number of trap days for each survey farm.

Farm ID	Number of Cameras	Start Date	End Date	Total Trap Days	Camera Trap Brand	Habitat Type	Carnivore Species Recorded
A	3	09/10/2019	20/11/2019	129	Browning	Water Dam	Black Backed Jackal
					Browning	Kraal, Road, Bush	None
					Browning	Road, Bush	None
B	4	23/01/2020	05/03/2020	117	Browning	Kraal, Bush	Brown Hyena, Caracal
					Browning	Kraal, Bush	None
					Bushnell	Kraal, Bush	None
					Bushnell	Bush, Water, Pan	Brown Hyena
C	5	07/02/2020	21/03/2020	189	Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Bushnell	Kraal, Road, Bush	None
					Bushnell	Kraal, Road, Bush	Brown Hyena
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
D	4	08/10/2019	19/11/2019	164	Browning	Bush	Black Backed Jackal, Brown Hyena
					Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena, Caracal
					Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena, Leopard
E	4	21/10/2019	02/12/2019	172	Browning	Kraal, Bush	Black Backed Jackal
					Moultrie M-880	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Moultrie M-880	Kraal, Bush	Black Backed Jackal
					Moultrie M-880	Kraal, Road, Bush	None
E2	6	26/03/2020	07/05/2020	213	Browning	Kraal, Road, Bush	Brown Hyena
					Browning	Kraal, Road, Bush	Brown Hyena
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena, Leopard
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena, Leopard
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Bushnell	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena, Leopard
F	3	30/09/2019	11/11/2019	118	Browning	Water Dam	Black Backed Jackal, Brown Hyena, Caracal
					Browning	Bush, Road	Black Backed Jackal, Brown Hyena

					Browning	Dry Riverbed, Bush	Black Backed Jackal, Brown Hyena
G	4	17/09/2019	29/10/2019	79	Browning	Kraal, Road, Bush	None
					Browning	Kraal, Road, Bush	Black Backed Jackal
					Browning	Kraal, Bush, Crop Field	Black Backed Jackal, Leopard
					Browning	Kraal, Bush	None
H	7	11/02/2020	24/03/2020	263	Browning	Kraal, Road, Bush	Brown Hyena
					Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Browning	Kraal, Road, Crop Field	None
					Browning	Kraal, Road, Crop Field	None
					Browning	Kraal, Road, Bush	None
					Browning	Kraal, Road, Bush	Black Backed Jackal, Brown Hyena
					Bushnell	Kraal, Road, Bush	Black Backed Jackal
I	5	11/02/2020	24/03/2020	126	Browning	Road, Fence, Bush	None
					Browning	Road, Fence, Bush	None
					Browning	Bush, Road	None
					Bushnell	Bush, Road	None
					Bushnell	Bush, Road	None
J	4	23/01/2020	05/03/2020	163	Browning	Road, Bush	Brown Hyena
					Browning	Water Dam	Black Backed Jackal, Leopard
					Browning	Road, Bush	Black Backed Jackal, Brown Hyena, Leopard
					Browning	Road, Bush	Black Backed Jackal
K	4	19/11/2019	31/12/2019	88	Browning	Kraal, Bush	Black Backed Jackal
					Browning	Kraal, Bush	Black Backed Jackal
					Browning	Kraal, Bush	None
					Browning	Kraal, Bush	Black Backed Jackal

Four carnivore species (brown hyena, black blacked jackal, caracal, and leopard) were recorded on the camera traps (Tables 4.3 and 4.4). Smaller species such as serval (*Leptailurus serval)*, African wild cat (Felis lybica), small spotted genet (*Genetta genetta),* large spotted genet (*Genetta tigrine*) and honey badger (*Mellivora capensis*) were recorded but not included in analysis as they were not reported by farmers to cause livestock damage. Carnivore species were not recorded on 17/53 camera traps but all farms except one (I) had at least one carnivore species detected once by camera trap across the study period.

Table 4.4: Detection rate (%) for each carnivore species on each farm. Detection rate was calculated by dividing the number of detections by total number of trap nights on each farm.

Carnivore Species	**Farm ID**											
	A	**B**	**C**	**D**	**E1**	**E2**	**F**	**G**	**H**	**I**	**J**	**K**
Black Backed Jackal	18.6	0	14.29	47.56	45.34	9.34	39.83	2.53	16.73	0	9.2	29.55
Brown Hyena	0	4.27	8.47	11.55	1.75	7.98	28.81	0	3.42	0	1.23	0
Caracal	0	2.56	0	7.32	0	0	0.85	0	0	0	0	0
Leopard	0	0	0	0.61	0	3.29	0	1.27	0	0	1.23	0

Black backed jackal were the most frequently recorded species on most (9/11) farms; some black backed jackal were recorded in pairs. Leopard, brown hyena and caracal were detected less frequently and were only recorded as individuals.

No direct interactions between livestock and carnivores were recorded on camera and there were no images containing both livestock and carnivores (i.e., no indirect interactions). Black backed jackal, brown hyena, caracal and leopard were detected inside of kraals at least once on five farms, with the majority of farms determined to experience visits outside of a kraal (Table 4.5). Caracal and brown hyena were recorded drinking water from within kraals but the behaviour of the other carnivores inside kraals was undeterminable. Furthermore, it was not possible to determine whether livestock were present in kraals at the same time as carnivore detections (livestock were not captured in the same image as carnivores but may have been out of view of the camera trap).

Table 4.5: Carnivore species detected inside and outside of the kraal on all farms.

Farm ID	Inside Kraal	Outside Kraal
Farm A	None	Black Backed Jackal
Farm B	Caracal, Brown Hyena- Drinking water	Brown Hyena
Farm C	None	Black Backed Jackal, Brown Hyena
Farm D	Black Backed Jackal, Leopard	Black Backed Jackal, Brown Hyena, Caracal
Farm E	Black Backed Jackal	Black Backed Jackal, Brown Hyena
Farm E2	Brown Hyena	Black Backed Jackal, Brown Hyena, Leopard
Farm F	None	Black Backed Jackal, Brown Hyena, Caracal
Farm G	None	Black Backed Jackal, Leopard
Farm H	None	Black Backed Jackal, Brown Hyena
Farm I	None	None
Farm J	Black Backed Jackal	Black Backed Jackal, Brown Hyena, Leopard
Farm K	None	Black Backed Jackal

Carnivore species presence classification based on the percentage of detections derived from camera trap data across all survey locations is shown in Table 4.6.

Table 4.6: Classification of carnivore presence derived from detection rate using camera trap data from all farms.

Carnivore Species	% of detections (number of detections divided by total trap nights)	Presence Classification
African Wild Dog	0	Absent
Black Backed Jackal	19.80	High
Brown Hyena	5.77	High
Caracal	0.87	Medium
Cheetah	0	Absent
Leopard	0.60	Low
Spotted Hyena	0	Absent

4.3.2 Activity Overlap

To assess activity overlap, camera trap data from all farms were combined and three categories- livestock, farm activity and carnivores, were used for analysis (Table 4.7). The category ‘livestock’ included independent records of cattle, goat, sheep, and horses. Carnivores included black backed jackal, brown hyena, caracal and leopard. Farm activity included presence of people (farmers, workers and vehicles). Overlap with carnivores and livestock were also assessed separately for farmers. Farmers tended to be in a vehicle rather than on foot and were therefore counted as vehicle alone, as such the sample size was smaller than 50 and overlap was estimated using Δ_1.

Table 4.7: The categories used to assess activity overlap and number of independent records for each category.

Category	Number of independent records
Farm Activity	1591
Livestock	1148
Carnivore	493
Farmer	43

Livestock, carnivores and farm activity showed different coefficients of overlapping (Table 4.8).

Table 4.8: The overall kernel density estimates for each of the categories and 95% bootstrap confidence intervals.

	Kernal Density Estimation of Overlap (Δ4)	95% Bootstrap Confidence Intervals
Carnivores and livestock	0.399	0.361-0.438
Carnivores and farm activity	0.221	0.188-0.255
Livestock and farm activity	0.797	0.770- 0.824
Farmers and carnivores	0.248 Δ_1.	0.163-0.308
Farmers and livestock	0.7213 Δ_1.	0.605-0.827

Livestock and carnivores had a low level of overlap with carnivores; carnivores were most active at night with most detections between 6pm- 6am, whilst the majority of livestock detections were recorded between 12- 6pm (Figure 4.3a). Carnivores and farm activity had the least amount of overlap (Figure 4.3b). Livestock and farm activity had a high level of overlap (Figure 4.3c).

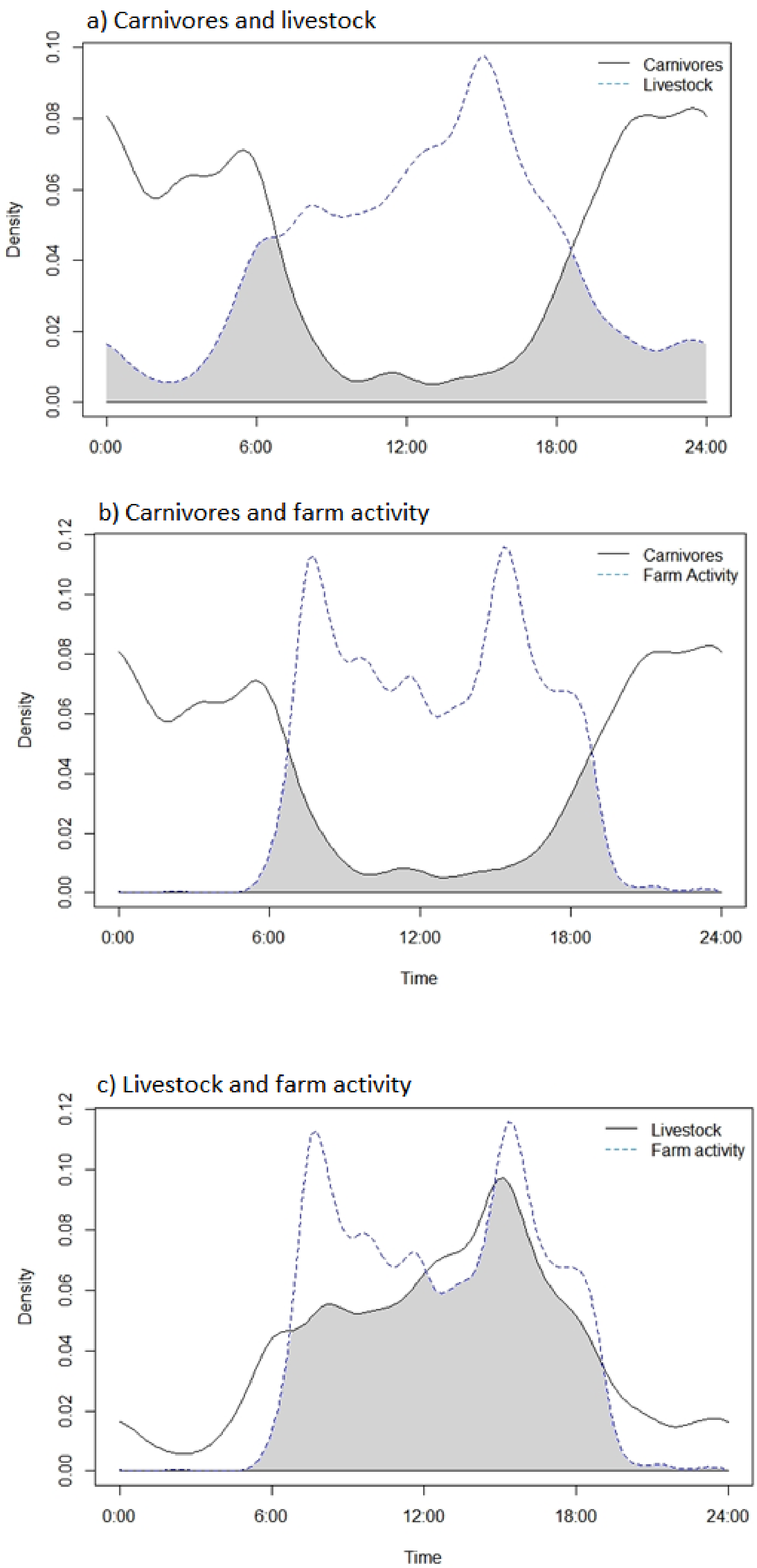

Figure 4.3: Overlap density plots for a) livestock and carnivores, b) carnivores and farm activity and c) livestock and farm activity. The coefficient of overlap is represented by the shaded area and detection times are shown along the x axis.

Farmers were most active at dawn and dusk, and therefore had a low overlap with carnivores (Figure 4.4a). Farmers and livestock showed overlap during the day with livestock activity peaking before 6pm (Figure 4.4b).

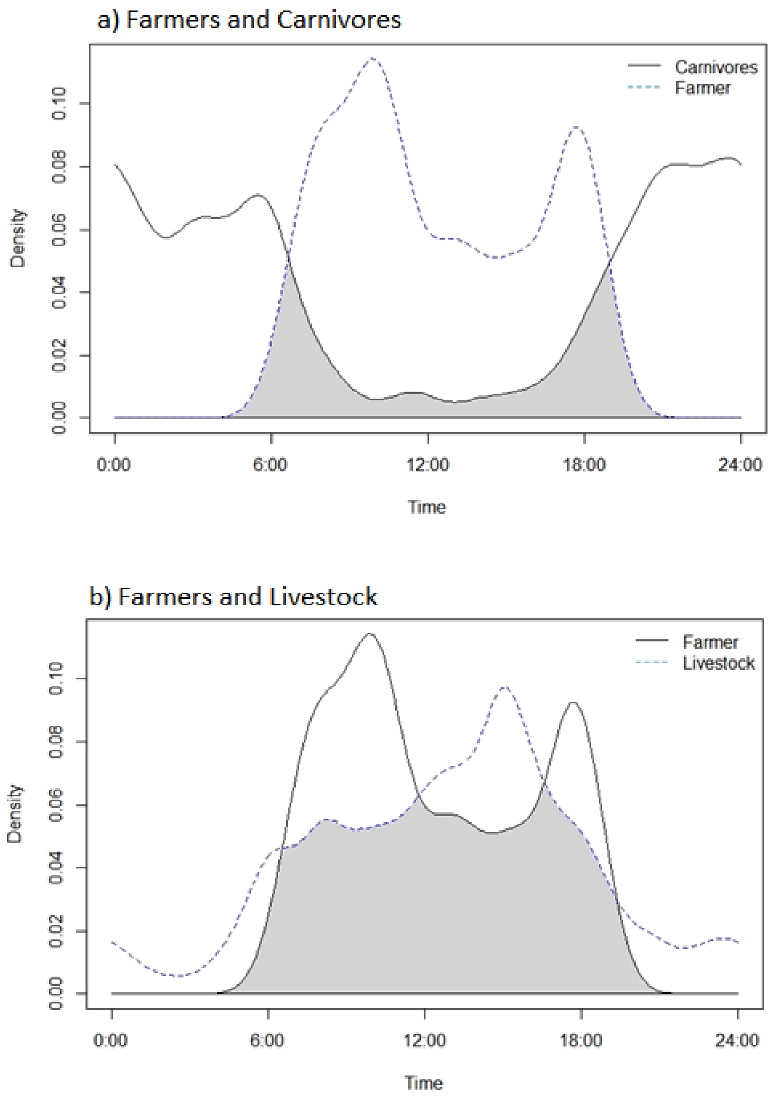

Figure 4.4: Overlap density plots for a) farmers and carnivores and b) farmers and livestock. The coefficient of overlap is represented by the shaded area and detection times are shown along the x axis.

4.3.3 LEK findings

In total, thirty-one interviews were conducted: 20 commercial farmers, seven NGO workers, three PAA and one private tourism operator (see chapter 2, Tables 2.3 and 2.4 for participant profiles). Eight of these farmers participated in the camera trap study; one farmer owned a property and rented another for other livestock; thereby, of the 12 camera locations, nine sites had both interview and camera trap data.

Species Presence

A total of seven different carnivore species were identified in the LEK data as being present across the nine farm sites with both LEK and camera trap data (Table 4.9). Reported presence was categorised into main species (always present), occasional (passes through the property) and rare (has been seen in the past).

Table 4.9: LEK reported carnivore presence per farm.

Farm ID	Present				Occasional		Rare	
A	Leopard	Hyena	Caracal	Jackal				
B and J	Leopard	Brown Hyena	Jackal	Caracal	Cheetah			
C	Jackal	Leopard	Brown Hyena	Caracal	Cheetah	Wild Dog		
F	Leopard	Caracal	Hyena					
G	Leopard	Brown Hyena	Caracal	Jackal				
H	Jackal	Caracal	Brown Hyena	Leopard	Spotted Hyena		Cheetah	Wild Dog
I	Brown hyena	Leopard			Spotted Hyena			
K	Jackal	Caracal	Leopard	Brown Hyena	Cheetah			

Carnivore species presence classification was derived from LEK data and based on the number of times each species was coded as having a present, occasional, or rare presence in interview data (Table 4.10).

Table 4.10: Classification of reported carnivore presence derived from LEK data.

	Reported Presence				
Carnivore Species	**Present**	**Occasional**	**Rare**	**Not Reported**	**Classification**
African Wild Dog	0	1	1	6	Low
Black Backed Jackal	6	0	0	2	High
Brown Hyena	8	0	0	0	High
Caracal	7	0	0	1	High
Cheetah	0	3	1	4	Medium
Leopard	8	0	0	0	High
Spotted Hyena	0	2	0	6	Medium

Livestock-carnivore interactions

Participants were asked to estimate how often they perceived livestock to come into contact with carnivore species (see chapter 2.3.1 for details). Interactions were not limited to fatalities and included any occasions in which livestock and carnivores were thought to be in the same place at the same time.

Including data from all participants (31), livestock were reported to interact with the following carnivore species: Black backed jackal, leopard, spotted hyena (*Crocuta crocuta*), brown hyena, caracal, cheetah (*Acinonyx jubatus*), wild dog (*Lycaon pictus*), martial eagle (*Polemaetus bellicosus*), and python. It was reported that black backed jackal were most likely to interact with livestock and some farmers reported daily interactions. Interactions with larger species such as leopard were typically thought to be infrequent, occurring on a monthly or infrequent basis. It was reported that interactions were most likely to take place at water sources or at a kraal whereby livestock would be inside with carnivores passing on the outside.

Some participants (n=7; 5 conservationists, 2 farmers) declined to estimate interaction frequencies as they felt unable to answer accurately; NGO and PAA participants were less likely to estimate in comparison to farmers.

Interactions were detected by farmers through sightings of spoor, livestock depredation and changes in livestock behaviour including cattle standing rather than lying, signs of running inside of kraal and damage to kraal fences. There was awareness that not all interactions end in fatality. Furthermore, there was acknowledgement by some participants that the cause of livestock death can be hard to determine, for example, when animals are missing and the cause of their disappearance is unknown, and awareness that carnivores can be scavengers.

Fatal interactions between livestock and carnivores were reported as most likely to occur at night. Farmer participants described the majority of carnivores as being nocturnal species and most likely to move around the farm when farmers were not active.

Leopard were most frequently reported by farmers (n=15/20) as causing the most damage to livestock. Other species named as causing the most damage to livestock were, in no order: brown hyena, spotted hyena, jackal, and caracal.

The majority of NGO and PAA participants anticipated that farmers would blame leopard for causing the most damage (n=8/11). NGO and PAA participants were also asked which species they personally thought most likely to cause the most damage; a number of species were named including leopard, spotted hyena, brown hyena, black backed jackal, caracal and lion. Black backed jackal were named as most likely to cause damage to small stock (n=2).

Young livestock were considered most vulnerable to negative interactions with carnivores with calves being considered easy prey.

"*As soon as it's calving season then we start getting problems so it's when they're in calving season when's there's young ones it's a weekly thing but if you can look after that, the calves when they're like weaned then you don't have a problem*." F10

Camera trap use

Six farmer participants mentioned (without prompting) that they used camera traps for personal reasons, e.g., to aid in hunting. The use of personal camera traps was regarded as "the only way you can see what happening on your farm at night" F20 and that "through trail cams and this and that I've got a pretty good idea what's going on the place" F03. Camera traps were primarily placed at waterholes and used by farmers to understand wildlife numbers on their property.

"*When you download footage there will be a cheetah or leopard somewhere in there at a water hole or something. And that you can see with the amount, how often you see them on cameras*" F08.

"*On one property- ok it's a big property, it's 20,800 hectares (208km^2) but I know there's 24 leopards on it, camera traps put out on camera research has been done it's and predators are all over*" F10.

Concern was expressed by conservationists over the ability of farmer stakeholders to interpret camera trap images correctly and identify individuals.

"*So, if you have 20 picture of a leopard, they're going to think it's 20 leopard which is not, which is not possible so I think it could be harmful but it's not because it depends on where you use the camera.*" N03

This concern may be valid in some cases, for example, a farmer appears to have mistaken multiple detections of leopard in a single night as representing different individual leopards:

"*One night 13 leopards come to drink water. Not at once nee, one, one, one, one 13 on the camera…. Shit, [make them dead man, kill them].*" F04

However, evidence to refute the presence of 13 individual leopards is not available.

Some farmers expressed scepticism of the camera trap methods used by NGOs to generate local population estimates as the survey results seemed to contradict their own camera trap findings.

"But that grid it's maybe alright for er, for the but it's not a accurate measurement for what's the amount of predators in our area because they if you put it at the water and you can identify it with spots like the leopards and then you can maybe get a better idea of predators or leopards in the area." F16

“With these trap cameras we saw, all the people saw find the leopards on the camera and then they become a big problem.” F20

4.3.4 Complementing LEK and camera data

Camera trap and LEK presence classifications for each carnivore species were then assessed alongside each other (Table 4.11). Classifications were generally lower when using camera trap data than LEK and no species presence was ranked equally by camera trap and LEK classification. In most cases (5/7 species), rankings differed by at least two orders.

Table 4.11: Presence classifications for camera trap and LEK data per species.

Carnivore Species	Camera Trap Classification	LEK Classification
African Wild Dog	Not detected	Low
Black Backed Jackal	Medium	High
Brown Hyena	Low	High
Caracal	Low	High
Cheetah	Not detected	Medium
Leopard	Low	High
Spotted Hyena	Not detected	Medium

4.4 Discussion

Similarities and differences between LEK and camera trap data

4.4.1 Carnivore presence according to LEK and camera data

Seven species were named in the LEK data as being present on farms; of these, four (jackal, hyena, caracal and leopard) were detected by camera traps. Leopard were perceived as having a high presence however, camera trap detections were low. The mismatch in leopard presence classification may be indicative of biased perceptions held by the participants in which species that are considered to cause problems are thought to have the highest presence (Caruso *et al.,* 2017). Additionally, in some cases, multiple captures were interpreted as multiple individuals by farmers which may cause them to overestimate their presence. Alternatively, LEK may be a more reliable form of data for this species’ presence since leopard are known to be difficult to detect by camera trap (Pirie, Thomas and Fellowes, 2016). As such, their low detection here may not be representative of their true presence, particularly if camera deployment was not optimised for this species specifically.

In a study conducted approximately 70km from the study site, the leopard population was reported to have suffered a significant decline (Williams *et al.,* 2017). Using camera trap data, leopard decreased from 10.7 leopards per 100km² in 2008 (Chase Grey, Kent and Hill, 2013) to 3.7per 100km² in 2015 (Williams *et al.,* 2017). This decline has been driven by high levels of human induced leopard mortality (Williams *et al.,* 2017). Furthermore, a spatial capture-recapture study from Platjan- a predominantly agricultural, mixed land-use system north of the current study site, estimated the leopard population as 2.2 leopards per 100km² (Faure *et al.,* 2021). Whilst the camera traps used in this study were not set up to measure species density or abundance, these previous studies suggest that the leopard population in the study area is likely to be low. In comparison, the LEK data suggests at least one leopard living on each property (i.e., always present, and not just passing through). All properties included in the study were smaller than 100km²; given that the average adult female leopard home range is estimated to be only 30km² (Braczkowski *et al.,* 2016), it is feasible that each property had at least one resident leopard which may shape the LEK presence estimations. Low camera trap detections could therefore match farmer's perception that there is at least one individual always present on the property, especially since this species is elusive and one individual would be expected to have low detectability on camera traps. The differences discussed here may therefore reflect the spatial and temporal scales at which data are collected for example, measuring according to frequency of detection versus permanence of an individual's residence.

Spotted hyena, cheetah and African wild dog were not recorded on camera traps; spotted hyena and cheetah were perceived by LEK participants as having a medium presence whilst African wild dog were considered to be low. Findings from a previous study indicated that they may pass through the wider Soutpansberg area occasionally (Williams *et al.,* 2018), and as such it is unlikely that they would have been detected in camera traps during the timeframe of this study. In this context, LEK may offer a potentially more robust means of assessing the presence of these species in this region than discrete, short-term camera trap studies could, although we acknowledge that our camera trap survey was targeted at interaction hotspots and therefore not designed to determine spatial patterns. Nonetheless, the longer timeframe over which farmers are able to observe their properties may offer advantages when investigating species with only intermittent or transitory occurrence. Brown hyena density in the Soutpansberg was estimated at 3.6 per 100 km² (Williams *et al.,* 2017) and 0.74 brown hyenas per 100km² in Platjan (Faure *et al.,* 2021). In Southern Africa, densities of brown hyena have been recorded to be higher on cattle farms than neighbouring protected areas (Kent and Hill, 2013), potentially as a means of avoiding competition with lions and spotted hyena (van der Weyde, Mbisana and Klein, 2018). Such behavioural adaptations align with the high presence classification obtained for this species on farmlands from the LEK data in this study, however, camera detections were low.

It is important to acknowledge that LEK data is developed over time and is influenced by numerous factors including time spent in the area (Petracca *et al.,* 2018; Madsen *et al.,* 2020). In contrast, camera trap images provide only a snapshot of a specific location in a given timeframe. Camera trap survey effort was therefore low in comparison to the timeframe that shapes LEK perceptions. Following this, we recognise that the timeline to which ecological sampling methods and semi-structured interviews were carried out may influence the points of divergence on carnivore presence between both knowledge systems. Furthermore, we acknowledge that LEK data may include misidentifications of species. Participants' ability to correctly identify carnivore species from images was not tested however, they are usually considered proficient by researchers (Rutina *et al.,* 2017).

4.4.2 Frequency of interactions

No interactions between livestock and carnivores were recorded on camera traps. Activity overlap between livestock and carnivore species activity was low suggesting that livestock and carnivores may utilise areas at or around livestock kraals at different times. Black backed jackal, brown hyena, caracal and leopard were recorded inside of kraal fences, however, these images did not contain livestock. Caracal and brown hyena were recorded on camera using kraals to access water sources, demonstrating that carnivore species may use resources (other than livestock) made available by livestock farming. Similarly, LEK participants named water sources as a location where interactions were most likely to occur. Land use has been recorded as a key factor in influencing carnivore occupancy and it has been suggested that some carnivore species may prefer to utilise occupied farmlands in order to gain access to livestock boreholes and avoid competition with large carnivores (van der Weyde, Mbisana and Klein, 2018).

LEK participants perceived black backed jackal to interact most regularly with livestock. Despite the lack of interactions recorded on camera traps, black backed jackal were the most frequently recorded carnivore species on the camera traps, giving them the greatest chance of being in the same place at the same time as livestock. The fact that this relatively high visitation rate did not result in livestock injury or fatality is particularly encouraging of the capacity for coexistence to occur. Interactions between livestock and leopard or brown hyena were reported by participants to happen monthly or less, but were not detected by camera traps, again highlighting the likely effect of different sampling periods.

4.4.3 Damage causing species

Four main species were identified in the LEK data as causing livestock depredation- black backed jackal, brown hyena, caracal and leopard. Although these were also the four species most commonly recorded on camera trap, no evidence of interaction (even passive or non-fatal) with livestock was detected. In other studies in Southern Africa, leopard, cheetah, caracal and black-backed jackal were also the most commonly reported species to cause sheep and goat losses (Marker, Mills and Macdonald, 2003; Thorn *et al.,* 2012). Cause of livestock loss is often inferred through indirect evidence such as spoor, bite marks and feeding behaviour, as described by Thorn *et al.* (2013). In the current study, leopard were most commonly reported in the LEK data as the species causing most damage to livestock. Such perceptions contrast with other studies that found jackal were most commonly blamed for livestock loss (Thorn *et al.,* 2012; Terblanche, 2020). Previous research has highlighted that blame can be assigned in the absence of confirmed causes of livestock loss (i.e., neglecting to consider other causes of loss including disease or theft) or where scavenging behaviour is incorrectly equated with predation (Marker, 2002). Brown hyena were reported to cause loss which contrasts with their known foraging strategy, which predominantly involves scavenging (Burgener and Gusset, 2003). As such that it is possible that brown hyenas may have been caught scavenging on livestock and incorrectly assumed to have been responsible for the death. Assignment of blame has been found to influence stakeholder behaviour or tolerance towards a species (Kross *et al.,* 2018). Such perceptions of damage causing species may indicate that whilst fatal interactions are likely to be infrequent, they can have long lasting impacts on people's perceptions towards particular species (Barua, Bhagwat and Jadhav, 2013; Blackie, 2022). Subsequently, people may associate species perceived to cause high levels of damage as also occurring frequently or in large populations (e.g., Whitehouse-Tedd *et al.,* 2021). Such perceptions can be explained by cognitive biases and is an example of the availability heuristic in which it is assumed that what comes to mind most easily, must occur most frequently (Tversky and Kahneman, 1973).

On this note, it was reported by LEK participants that jackal were sighted regularly whilst leopard were rarely sighted by farmers. Correspondingly, recorded activity overlap between farmers and carnivores was low. Farm activity was highest during the daylight hours, peaking at dawn when livestock are typically released from overnight enclosures for grazing, and again at dusk when livestock are returned to the kraal. The visibility of a species may therefore contribute to people's perceptions of livestock damage. In this current study, regular sightings of jackal may contribute to a greater awareness of their behaviours and acknowledgement that they do not always harm livestock. As such, it was recognised by participants that high visitation rates do not necessarily equate to high damage.

A number of factors affect the severity and frequency of livestock depredation, for example, proximity to protected areas, husbandry practises and availability of natural prey (Amit and Jacobson, 2017; Gebresenbet *et al.,* 2018). The farms on which the camera traps were placed varied from one another in many of these factors e.g., size, number of livestock, main income, mitigation method and location in relation to geographical features such as water and mountainous areas (see chapter 2, Table 2.3). These factors may lead to variation in carnivore behaviour or utilisation of the farm, as well as variation in livestock loss and hence contribute to farmer experiences and perceptions of carnivores. Whilst farmers were asked to estimate frequency of interactions per month, it is likely that they based their estimations on experiences across a much longer time period (see chapter 2.3.1). In contrast, the camera trap data reflect only the survey period and do not consider seasonal variation or account for the possibility of low months and high months which are likely to shape LEK perceptions.

4.4.4 Time of interactions

LEK derived data revealed that livestock predation was most likely to happen at night. Similarly, the camera trap data showed that carnivore species were most active during the night with minimal activity during the day. This convergence between knowledge sources aligns with a previous study that used records of predation incidents and found livestock predation by leopard and hyena most likely to take place at night (Kissui, 2008). Assessment of activity overlap showed that livestock and carnivore species had differing activity patterns with the most overlap occurring at dawn and dusk. Previous studies have found that apex carnivores outside of protected areas showed strong temporal partitioning with pronounced nocturnal behaviour (Odden *et al.,* 2014). Furthermore, lions living near human-modified landscapes have been seen to move faster on darker nights (Snyman *et al.,* 2018). Carnivore species are therefore known to make fine-scale spatiotemporal adjustments to avoid areas considered high risk, which may help to explain the activity patterns seen here by farmers and via camera trap detections. Livestock predation was considered by farmers most likely to happen at night when farm activity was low, further supporting the notion that carnivores move when they are least likely to be detected by humans.

Whilst recorded overlap between carnivores and livestock was low, it does not necessarily mean that livestock are not predated on. Leopard, for example, are opportunistic hunters (Hunter, Henschel and Ray, 2013) and have rarely been found to be active at the same time as their main prey species (Hayward and Slotow, 2009). Furthermore, camera traps scarcely capture hunting behaviour and given the ambush hunting strategy used by many carnivore species, it is very difficult to determine whether temporal overlap between leopards and their prey species is direct evidence of leopards targeting them (Havmøller *et al.,* 2020). Direct observations of carnivores predating livestock are rare (Havmøller *et al.,* 2020) and usually it is only the livestock carcass that is found, making it hard to determine the cause of death, as acknowledged by some LEK participants in this study.

4.4.5 How the use of different knowledge systems can inform HCC scenarios

The camera traps in this study were used by researchers to better understand livestock-carnivore interactions. During the process of the study, it became apparent that camera traps were also used by farmer stakeholders as a device to monitor and better understand what was happening on their property. Some farmer participants in the study used camera trap images to identify what they considered to be the cause of their problems, for example, an image of a leopard may be interpreted as a leopard being a problem animal. It also emerged that NGO stakeholders queried farmer use of camera traps to monitor wildlife. Conservationists may therefore feel that personal use of camera traps by farmers can hinder the NGO's work and could be used to detect carnivores for purposes that may be counter to conservation. Similarly, farmers may not trust the results generated by scientific approaches if they feel they do not reflect their own perceptions or camera trap findings. Camera trap use and image interpretation may subsequently cause or exacerbate human-human conflict.

The use of semi-structured interviews as an interview process allowed for the comments about camera trap use by different stakeholder groups to emerge; other more quantitative methods of collecting data on perceptions of carnivores or livestock-carnivore interactions, may have missed this. Whilst the study did not explicitly set out to ask about camera traps, the interview discussions gave rise to important points regarding camera trap use and image interpretation that have been included in this chapter. The emergence of such findings demonstrate how in-depth qualitative interviews can contribute to HCC scenario knowledge. The interviews also revealed how camera trap placement and image interpretation can be used to support or contradict conservation intentions, depending on stakeholder perceptions. The comments made during the interviews on camera trap use also demonstrate how the use of one data collection technique (interviews), can provide information about methods of obtaining other data collection techniques (camera traps) which would otherwise be overlooked.

Observations and conversations from the pilot study indicated that most carnivore visits to livestock kraals were undetected by farmers. These suggested that it would be worthwhile having a recorded discussion with farmers after the collection of the camera trap data to discuss their thoughts on the images collected, and whether they assist in determining if the intervention strategies employed were working or if they would behave or think differently after seeing the camera trap evidence. A previous study has suggested that communicating the findings of camera trap surveys back to farmers can help farmers to have a better understanding of whether the intervention strategies they utilise are helping to reduce loss (Zak and Riley, 2017). Sharing images of carnivore visits that do not result in livestock injury or loss may subsequently prove important in increasing stakeholder tolerance of carnivores on their property. However, following comments made by a minority of participants, the sharing of these images was decided against because of the potential risk posed to wildlife. It was identified that information may be used to target wildlife for persecution, and such response even by just one participant, warranted a precautionary approach. This raises debate over the ethics of camera trap use. The study was conducted on private land with the permission of the landowner and subsequently there was awareness that data from camera traps were being collected. Prior to the study, a data management plan was developed, and participants consented to images to be taken. However, the consent form did not explicitly state whether participants had a right to see the images; in retrospect, it should have. Data sharing with stakeholders, whilst important, can have potential complications (Sharma *et al.,* 2020). For example, geo-referenced camera traps images could be used by poachers (Lindenmayer and Scheele, 2017) if they became accessible to this stakeholder group. Whilst poaching was not identified as a threat in the current study, the ethical issues identified here also stem from the potential for undesirable or controversial use of recorded images and whether landowners have a right to see the images collected. Literature on the ethical dimensions of camera trap use in conservation has primarily focused on minimising impacts to wildlife themselves (Rebolo-Ifrán, Grilli, and Lambertucci 2019) but has recently begun to address the potential impacts on people (Sandbrook *et al.,* 2021). However, there is little information about the image rights of camera trap data taken on private land. It is consequently recommended that future studies using camera traps on private land clearly set out image ownership rights and take steps to prevent images being used in a way that may be detrimental to HCC goals.

Misinterpretation of camera trap images could also contribute to perceptions that carnivore numbers and damage are higher than they actually are. Participant comments on the use of and interpretation of camera trap images suggested that not all users of camera traps apply the same protocol when interpreting camera trap data, especially regarding the techniques used to differentiate between repeat detection of a single animal versus detection of multiple individuals. The use of personal camera traps could subsequently exacerbate farmers' negative perceptions of carnivores through the production of cognitive biases in the form of availability heuristics (Tversky and Kahneman, 1973) and illusory correlations (Hamilton and Gifford, 1976) whereby images of large carnivores are most likely to be remembered, come to mind quickly and a relationship is then assumed between the number of images and population size. This may suggest that wildlife monitoring resources, which are accessible to anyone, are providing a means of justification for lethal control, or at least poor tolerance and associated attitudes and behaviours, through overestimation of carnivore numbers. Differing methods of image interpretation can therefore lead to opposing perspectives on carnivore population size and control. Given the availability of camera traps to purchase in South Africa and their use amongst participants, providing appropriate, and constructive, advice on image interpretation may help to increase understanding and tolerance of carnivores. However, it should be recognised that misinterpretation of camera traps is not unique to farmers. Errors in identification and classification are also seen in camera trap studies conducted by experienced conservationists (e.g., as reported by, Johansson *et al.,* 2020; Zett, Stratford and Weise, 2022). Likewise, the interval between repeat camera captures that is used to denote separate detections for species in which individuals cannot be identified is only arbitrarily set in most cases. The occurrence of repeat visits by one individual cannot therefore be indisputably distinguished from discrete visits by multiple individuals. Inter-observer bias and observer-related variables are therefore important considerations if camera trapping findings are used for population estimates (Zett, Stratford and Weise, 2022) or to inform HCC practises.

Identifying individuals, although difficult for many species, could be worth the investment of time in some contexts, e.g., on single farm case studies over long periods of time. This may further aid in achieving HCC goals, i.e., through awareness that there is one leopard on the property, rather than multiple. Increasing awareness about the scientific practice utilised for camera trap surveys could improve farmer trust of population censuses generated by conservations, which here emerged as a potential area for human-human conflict. Furthermore, increased collaboration between stakeholder groups, and the sharing of camera trap images, could provide conservationists with valuable data on carnivore presence and behaviour. The Ruaha Carnivore Project (RCP) community camera trapping programme shows that local communities can be successfully incorporated in camera trap studies with benefits to all stakeholders (RCP, 2019); adoption of similar approaches to community engagement would likely benefit other programmes.

Due to the placement strategy employed for camera traps in the current study, the cameras did not cover the entire perimeter of the livestock kraal and therefore some visitations may have been missed. If no carnivore visits or interactions were recorded at a site, it is not possible to know whether carnivores avoid the area (i.e., potentially due to use of intervention strategies), visit infrequently (i.e., not in the study duration), visited but were not detected, or are not present on the farm. For example, no carnivores were recorded at Farm I, but camera trap studies conducted by Alldays Wildlife and Communities Research Centre (AWCRC) -using different placement strategies and over a longer time period, confirm that leopard, hyena, jackal and caracal are present on that farm (McKaughan, J, personal communication). Long term studies of carnivore species presence on the farm would help to better understand the findings of this chapter and provide more in-depth understanding of perceived and camera-detected presence, however, this was beyond the scope of this study.

The camera traps used in this study did not provide evidence regarding livestock predation. Conclusions drawn from camera trap data about species interactions need to be considered with care and can only reflect that detectable species were in the same areas as the camera trap range, at the same time of day (Meredith, Ridout and Meredith, 2021). Combining camera trap data with reports of predation events, as was intended but not achieved due to low farmer engagement, would have enabled greater understanding and characterisation of predation events as well as the neutral interactions. Despite these limitations, complementing interview and camera trap data can provide new insights and the methods used highlight how camera traps can be used, or whether they should be used, to better understand and manage HCC.

4.4.6 Reflections on the contribution of different knowledge systems to inform HCC scenarios

The use of different knowledge systems, in this case LEK and camera trap-derived knowledge, allowed for convergences and divergences to be explored; in particular, this approach highlighted differences in perceptions between stakeholder groups (farmers, conservationists and this independent researcher). Tensions between stakeholder groups about using information generated from different knowledge sources to inform wildlife management practises has previously been documented in South Africa (Terblanche, 2020). By using different knowledge systems, areas with potential for human-human conflict also emerged in the current study. In parallel, this study reflects human-human conflict on a broader scale in which a belief appears to exist within the academic and scientific literature that one form of knowledge (scientific) is superior to others (in this case LEK). A variety of human-human conflicts have been exposed here and include debate about the use of community- vs camera-derived knowledge as well as research-derived vs lived experience-derived. This is not to say that scientific researchers and academics need to utilise all sources of knowledge in their approaches to HCC- it is in their background and training to apply scientific thinking and practices, but rather to ensure that this bias is recognised along with an acceptance that there are different ways to generate knowledge.

4.5 Conclusion

The current study brings into focus a number of advantages and disadvantages of camera traps; findings in the LEK data raise many questions about the use of camera traps to inform HCC scenarios. As emerged here, how camera traps are utilised and for what purpose ultimately depends on who the user is i.e., researcher, farmer or conservation NGO. As such, the camera trap and its images can be used to justify any particular narrative and can be used by different stakeholders to tell a story that suits their rhetoric. In this way, each stakeholder group considers their perspective as the truth. LEK holders subsequently cannot just be viewed as bystanders to scientific research. They are knowledge producers themselves and scientists would benefit from engaging in more observation and lived experience research akin to the LEK generation method. All knowledge producers therefore need to be involved in the research process, including problem identification, research design and interpretation processes. Such a need has been previously recognised and forms the basis of participatory action research in which researchers and participants work together to understand and take action to improve a particular situation (Baum, MacDougall and Smith, 2006). Whilst knowledge co-creation can be time consuming, building effective and transparent relationships can help reduce the chance of data misuse (Mishra *et al.,* 2017). Furthermore, it is important to recognise that people will act on perceptions regardless of whether or not they are supported by scientific evidence (van Eeden, Eklund, *et al.,* 2018). For example, in Namibia and South Africa the use of lethal control methods by commercial farmers appears to be driven more by perceptions of carnivores than actual livestock losses (Potgieter, Kerley and Marker, 2016). An understanding and awareness of neutral interactions may hence aid in changing perceptions of and behaviours towards carnivores. Therefore, it is predictable that the achievement of HCC goals requires that perceptions of all stakeholders are understood and included. Overall, this study demonstrates that inclusion of multiple knowledge sources can contribute to a better understanding of HCC scenarios.

Chapter 5: Production of stakeholder-derived recommendations for evaluating success in the mitigation of human carnivore conflict scenarios

5.1 Introduction

In order to increase human carnivore-coexistence (HCC), various intervention strategies have been implemented with the aim of reducing negative outcomes of any interactions for both people and carnivores. There has been much debate in the literature as to how best to measure the effectiveness of different interventions (Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018; Khorozyan and Waltert, 2021). Depredation of livestock by carnivores is a predominant factor in human-carnivore interactions, hence the majority of intervention evaluations focus on a reduction in livestock loss after implementation (Miller *et al.,* 2016; Holland, Larson and Powell, 2018). However, achievement of HCC goals depends on many factors such as human behaviour change, including the consistent use and maintenance of interventions and a reduction in carnivore persecution (Nilsson, Fielding and Dean, 2019; Zorondo-Rodríguez, Moreira-Arce and Boutin, 2019). As an essential starting point in understanding stakeholder engagement with intervention strategies, it is therefore necessary to understand how users and advocates perceive and measure the success of these interventions. Other surveys, (e.g., Van Heel *et al.,* 2017), have noted significant differences among stakeholder groups in regards their perceptions of large carnivores and management preferences. Differing perspectives on the success and feasibility of intervention strategies may lead to animosity between stakeholder groups (van Heel *et al.,* 2017) and varied or sub-optimal uptake. Neglecting stakeholder perceptions can also lead to an incorrect assessment of intervention success (Gore and Kahler, 2012). Further, it is acknowledged that research should involve all stakeholders from the outset and recognise the contribution of different sources of knowledge (see chapter 4). Recommendations for measuring success must therefore be derived from stakeholders, accommodating diverse perspectives and identifying some consensus among stakeholders before they will be meaningful or valid in field applications. As a result, there is a need for evaluations to sufficiently consider the perspectives of all stakeholders. This can be difficult if stakeholders are from diverse groups and their perspectives are rooted in differing values (Lute and Gore, 2019). Understanding complex issues such as the implementation and evaluation of HCC interventions subsequently requires work across several disciplines, e.g., conservation biology, anthropology, social psychology and geography (Pooley *et al.,* 2017; Zimmermann, McQuinn and Macdonald, 2020).

This study draws on the key findings of stakeholder perceptions of success, and factors involved in such success derived from grounded theory interviews (see chapter 3A, (Lucas *et al.,* 2022)). Whilst it emerged that the majority of stakeholders (n=23/31) based their measures of intervention success on a reduction in livestock loss, perceptions were varied and shaped by many cultural, social, political and economic factors. Using these previous findings, recommendations for measuring HCC intervention success were developed and a Q-method survey was used to determine areas of consensus and disagreement among stakeholders' viewpoints. Q-method is well suited to understanding stakeholder perspectives to effectively understand the feasibility of conservation interventions and determinants of success, as well as anticipate and identify ways to manage potential disagreements (Mazur and Asah, 2013).

This study aimed to produce stakeholder-derived recommendations for measuring success in HCC and has two aims, as follows:

- Develop a draft suite of recommendations for measuring success and the factors contributing to success based on previously identified stakeholder perceptions.
- Determine areas of stakeholder consensus and disagreement regarding these recommendations in order to produce a final set of stakeholder-endorsed recommendations.

5.2 Methods

5.2.1 The Q-Methodology

Q-method is a unique semi-quantitative technique enabling the incorporation of a range of views on the topic being studied (Brown, 1980; Zabala, Sandbrook and Mukherjee, 2018). It is an interactive methodology that requires the respondent to make considered decisions and choices between predefined statements about the topic. Detailed explanations of the Q-method process can be found in Watts and Stenner (2012) and Webler *et al.,* (2009). Importantly, Q-method is used to determine the range of perspectives among participants, rather than the frequency of views. In this way, the method does not seek to survey a statistically representative sample, but rather the researcher ensures participants are representative of a comprehensive range of views about the topic in question (Chamberlain, Rutherford and Gibeau, 2012). Reliable results can therefore be produced even with small sample sizes (Brown, 1980; McKeown and Thomas, 1988; Coogan and Herrington, 2011).

In Q-method, participants express their perspectives by rank ordering a set of statements that cover a range of views on the subject being investigated (whereby the ranking process is known as the Q-sort) (Zabala, Sandbrook and Mukherjee, 2018). The statements are typically sorted onto a distribution grid from 'most agree' to 'most disagree' whereby the process allows participants to express themselves without conforming to preassigned categories (Rastogi *et al.,* 2013). After, the completed Q-sorts are correlated and factor analysis is used to identify participants with shared viewpoints as well as areas of agreement and disagreement between factors (Cross, 2005). The researcher plays an active role in shaping the analysis and interpretation of the results, which is grounded in their knowledge of the study topic (Zabala, Sandbrook and Mukherjee, 2018).

5.2.2 Developing the Q-set

Chapters 2 and 3A report on the use of grounded theory interviews to explore stakeholder perceptions of HCC and measures of intervention strategy success. The full interview process and subsequent findings are detailed in these chapters. Key themes identified in chapter 3A were used as the foundation from which the spectrum of perceptions on intervention strategy success were defined in this current chapter. These themes were used to construct the Q-sort, i.e., the suite of statements that the participants ranked (Zabala, Sandbrook and Mukherjee, 2018). A Q-set of 55 statements was initially derived from the interview transcripts with the aim of fully representing the themes identified in chapter 3A and the different viewpoints of interview participants. Statements were developed by the researcher selecting key coded phrases and quotes that captured the primary sentiment of the theme as well as those representing extreme ends of the spectrum within the theme. To further ensure that the full range of perspectives was covered, quotes were selected from participants that expressed interesting or opposing views. Similar quotes were merged to form summary statements. Where direct quotes were used as statements it was ensured that these could not be traced back to the originator. Other statements were developed by the researcher to reflect key themes that were not otherwise represented in the Q-set. These were then refined to an initial set of 39 statements following discussion within the research team. Criteria for inclusion were that statements focused only on participants' measures of and factorings contributing to success and did not cover perceptions of the success of specific intervention strategies. Statements with duplicate or overlapping meaning were removed and ambiguous statements re-written for clarity.

5.2.3 Q-sort pilot survey

The use of a pilot study is considered essential in Q-method and was conducted to ensure the Q-set was relevant, comprehensible, the statements were interpreted correctly, and that an appropriate number of statements was used (Coogan and Herrington, 2011; Zabala, Sandbrook and Mukherjee, 2018). Furthermore, the pilot study tested the online survey platform (https://qmethodsoftware.com/) for ease of use. Four participants involved in the previous study (see chapter 2.2.3 for methodology) completed pilot Q-sorts; one participant was a conservation stakeholder who had previously acted as a key informant (i.e., someone with specialist knowledge relevant to the study (Newing, 2011)), two others were conservation stakeholders who had previously acted as gatekeepers (i.e., someone who is in a position to establish connections and/or give permission for the research (Newing, 2011)), and the fourth was a farmer who had also acted as a key informant. Whilst ideally the pilot study would have been completed by representatives of all stakeholder groups, it was decided not to include a protected area authority (PAA) stakeholder in the pilot study as that group was only represented by three participants and inclusion in the pilot would have precluded their participation in the main Q-sort survey.

The findings from the pilot sorts were used to revise the Q-set and process. Following feedback from the pilot participants, six statements were cut to avoid repetition, three were added to ensure full coverage of all themes and 15 statements were edited and shortened for better clarity, and to avoid cognitive fatigue. The use of the pilot study resulted in a final set of 36 statements (Table 5.1). Other amendments were made to the methodology, including the instructions being shortened to limit words and ensure the survey was not daunting, whilst still conveying all the necessary information. Some edits were made to the instructions to clarify the meaning of terms, e.g., what exactly was meant by the term ‘mitigation strategy’ in relation to the study. The term mitigation was used in the Q-set rather than intervention as pilot participants deemed this to be more appropriate and commonly understood. However, for the purposes of reporting, the terms mitigation and intervention are used interchangeably, for example where necessary to align with terminology used in previous chapters relevant to the current study. Lastly, the anticipated duration of the survey was changed from one hour to 30 minutes, as a result of the pilot Q-sorts. Overall, the pilot study refinement process ensured the Q-sort would capture as much information as possible whilst not overloading the participants with statements (Zabala, Sandbrook and Mukherjee, 2018).

Table 5.1: Final Q-set statements used to explore measures and factors contributing to stakeholder perspectives of success in human-carnivore coexistence intervention scenarios and associated numbers for each statement (1–36).

	Q-set Statements: Measures and factors contributing to perceptions of success in HCC intervention scenarios
1.	Success is less incidents of livestock being killed by predators
2.	No livestock losses is the main measurement of success
3.	Success is measured as declining predation as indicated by farmers
4.	Successful mitigation methods prevent theft as well as loss to predators
5.	Success is measured by testing different methods and a control with no mitigation then comparing which is best
6.	Success is measured by increasing the % of livestock young successfully raised

7.	Losses before mitigation are often inflated which makes comparing before and after losses difficult
8.	Success needs to be measured long term
9.	Success of a new mitigation method can take some time to see
10.	Successful methods will produce immediate results
11.	Having a waiting list to get a particular method is a sign it is successful
12.	Successful methods remove problem predators from the area
13.	Success can’t be measured, not having livestock loss is success but you don’t know what losses would be without the mitigation method
14.	Success of methods can’t be measured, it’s just one of those things
15.	Even with mitigation strategies, achieving zero livestock losses by predators is impossible
16.	You can manage losses with mitigation strategies but there’s no guarantee they can completely stop problems
17.	Cameras help show success of methods by showing passing predators haven’t got to livestock
18.	Success is increasing the energy needed by predators to get to livestock
19.	Success is measured by a reduction in interactions between livestock and predators
20.	Success is measured by no predator tracks inside the kraal
21.	Successful methods deter predators from coming near to livestock
22.	Success is easier to achieve with money, if you don’t have money you will lose against predators
23.	For success, the cost of using and maintaining the mitigation method must be worth it
24.	Successful methods save money in the long term
25.	Success is changing the attitude of one person towards predators
26.	Success is changing people’s perceptions of predators
27.	Farmers are most likely to hear of successful methods through other farmers
28.	Farmers are more likely to trust the success of a mitigation method if they hear about it from other farmers
29.	Success can only be determined by the farmer
30.	Only scientists can determine success of mitigation methods
31.	Farmers and conservationists determine success in different ways
32.	Non-Governmental Organisations (NGOs) inflate the success rate of interventions
33.	Scientists can inflate the success rate of interventions
34.	Farmers expect mitigation placed by conservationists to work by stopping all livestock loss to predators
35.	Success is not guaranteed when mitigation is put in place by conservationists
36.	Success is best measured by collaboration between farmers and conservationists

5.2.4 Participant recruitment

In Q-sort, it is necessary to have fewer participants than statements and usually a ratio of 3:1 is used (Webler, Danielson and Tuler, 2009). Therefore with 36 statements, a target of 12 participants was set. To take part in the study, interviewees were required to either farm livestock, work in a protected area or private reserve, or for a wildlife conservation organisation within the study area. All participants were previous interview participants (chapters 2 and 3A) and subsequently known to the researcher in this capacity. Of the 31 interview participants, 22 were available to take part in the Q-method survey (13 farmers, 3 PAA and 6 conservation NGO workers). The tourism stakeholder was excluded having previously expressed that they were not interested in further participation. Six of the previously interviewed farmers could not participate as they did not have computer and/or internet access at their properties and Covid-19 restrictions at the time of the survey prevented survey completion in-person or via the use of public internet access points. One farmer had passed away and one had moved out of the area since the initial interview. As per the Q-sort process, participants were selected purposively with non-random sampling (Brown, 1980). The recruitment of participants was strategic and aimed to capture individuals who were likely to express interesting or critical views (Watts and Stenner, 2012). Therefore, those farmers invited to take part first were those who had demonstrated strong opinions (both positive and negative) about intervention success. Participants were initially contacted via phone to explain the process and asked if they would be willing to take part. On agreement, a link to the Q-sort was sent. Participants were then sent repeat invitations every week for three weeks; those that did not respond after this time were excluded from the study and other potential participants, those identified with the next strongest opinions in the previous interviews, were invited. Selective recruitment ensured a spread of participants across stakeholder groups and made certain a range of opinions and distinct perspectives were included.

5.2.5 Administering the Q-sort

Administration of the Q-sort took place from March- April 2021. Due to Covid-19 restrictions within South Africa at the time, the Q-sort survey was conducted online entirely using 'Q method Software' (https://qmethodsoftware.com/). Participants logged onto the survey using a unique ID code; after agreeing to participate and giving informed consent, participants were asked to read the instructions and were able to refer back to the instructions at any point during the sort. The instructions asked participants to sort the given statements onto a distribution grid based on their beliefs and experience about measuring intervention strategy success. It was explicitly stated that there were no right or wrong answers. The statements were then presented in a different randomised order to each participant, as generated automatically by the online programme. Firstly, participants were asked to sort the statements into three groups- agree, disagree, and neutral, by clicking on the appropriate symbol (thumbs up, thumbs down and neutral question mark). This was followed by the actual sorting phase where participants sorted the 36 statements into a forced choice array. This involved the participants dragging and dropping statements onto a grid with one space for each statement, approximating a normal distribution, where +5 was 'most agree' and -5 was 'least agree' (Figure 5.1). After completing the sort, participants could shuffle the statements within the grid until they were satisfied with their responses. The final placement of statements on the grid was entirely subjective and representative of the personal opinions of the respondent. Demographic data about occupation, home language, education level and religion were also obtained. On completion of the Q-sort survey, participants were invited to complete three non-compulsory exit questions to give feedback on the process and further details on their viewpoints.

					13					
				4	5	24				
			11	12	1	8	3			
		32	35	18	6	27	28	23		
	29	14	10	15	9	33	17	21	2	
30	20	34	19	36	7	16	25	26	31	22
-5	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**

Least Agree ← → Most Agree

Figure 5.1: Hypothetical example of a completed Q-sort. The numbers in each cell represent the placement of each statement of the Q-set, which are listed in Table 5.1.

5.2.6 Data analysis

Analysis was conducted using the PQMethod statistical programme which involves analysis for inter-correlations and factor analysis (Schmolck, 2014). Eigenvalues were calculated by summing the squared factor loadings of all the Q sorts on that factor. Together with the factor variance they indicated the strength of the factor. Factors with eigenvalues >1 and with more than one significantly loading Q-sort were considered significant (Watts and Stenner, 2012). Absolute factor loadings of ±0.33 or above were deemed significant at the $p < 0.05$ level. The selection criteria for factor extraction were based on visual interpretation of a scree plot (representing the Eigenvalues of the factors extracted) and the Kaiser-Guttman criteria. The scree plot showed a clear point of inflexion at Factor 2 and the Kaiser-Guttman criteria were satisfied when eigenvalues exceeded 1 (Watts and Stenner, 2012). Two factors, which represented distinct perspectives, were selected and refined using automated varimax rotation, which aimed to maximise the amount of variance explained by as few factors as possible (Webler, Danielson and Tuler, 2009). Varimax rotation is used as a standardised practice in Q-methodology in preference to manual rotation of the factors (Watts and Stenner, 2012).

The sorts that had a positive significant loading on each factor were flagged from their factor loadings (the degree to which a sort was exemplified by a factor). The flagging process was automated and conducted in the PQMethod software package. The factor loadings indicated the extent to which the individual Q-sort was similar to the composite Q-sort constructed to represent the factor, this is known as the factor array. Factor array scores showed where each statement was ranked (-5 to +5) in the factor array (composite Q-sort). Z-scores were presented and represented a weighted average derived from the contributing sorts. The factors were inspected and compared using the factor and z-scores to draw out defining features as well as areas of consensus and disagreement. Consensus statements, those which do not significantly distinguish between the factors (Jacobsen and Linnell, 2016), were identified. Consensus statements have the least amount of variance across factor z-scores and were used to determine areas of agreement between factors. Distinguishing statements for each factor were subsequently identified as statements with the most variance.

5.2.7 Ethical considerations

The project was approved by the Nottingham Trent University School of Animal, Rural and Environmental Sciences Ethical Review Group (protocol number ARE202121 for the Q-method and ARE880 for the previously conducted interviews). To ensure due care of all participants, the Q-method survey was explained in full upon invitation to participate. If participants agreed to take part, they were sent a digital link to the online Q-method survey. For reporting purposes, participants with an ID code prefix of 'N' represented a conservation focused stakeholder- either working for a conservation NGO or protected area authority, while the prefix 'F' was used to represent livestock farmers. Classification of participants in this way was based entirely on their occupation. On entry to the survey platform online, participants had to read an informed consent statement before agreeing to participate and then proceeding to start the survey (Appendix 4). Information was provided about their right to withdraw within a specified timeline and the process to follow for withdrawal. Personal data were anonymised prior to analysis.

5.3 Results

In total, 14 participants completed the Q-sort; seven livestock farmers, one PAA and six conservation stakeholders (Table 5.2). Six farmers and two PAAs did not respond after three reminder messages, no reason was given for their nonresponse, resulting in a response rate of 64%. With a Q-set of 36 statements and 14 participants, this provided a ratio of 2.5:1, and was therefore confirmed as appropriate (Webler, Danielson and Tuler, 2009). Using PQMethod a total of 14 sorts were tested for correlation among the Q-sorts and subjected to factor analysis.

Table 5.2: Demographic profiles for all Q-sort participants.

Age	Gender	Education Level	Occupation	Religion	Home Language
41	Male	Other	Farmer/ Professional hunter	Christian	Afrikaans
33	Male	Other	Farmer	Christian	Afrikaans

53	Male	University	Farmer	Christian	Afrikaans
53	Male	Secondary	Farmer	Christian	Afrikaans
55	Male	University	Game and crop farmer	Christian	Afrikaans
37	Male	Matric	Farmer	Christian	Afrikaans
29	Male	University	Farmer	Christian	Afrikaans
32	Male	Secondary	PA Manager	None	English
32	Female	University	Unemployed*	None	French
28	Male	University	IT Support Technician*	Christian	Afrikaans
36	Female	University	General Manager Conservation	Christian	English
45	Male	University	General Manager Conservation	Christian	English
37	Male	University	Coordinator for Conservation NGO	Christian	English
49	Male	University	Field officer for NGO	Christian	Afrikaans

*These participants had previously worked in conservation NGOs when they participated previously (see Chapter 2 and 3A) but were currently in different roles.

Two factors achieved Eigenvalues >1 and scree plot analysis confirmed the presence of two factors (Figure 5.2). It is recognised that there is less support for the existence of a second factor however, given the subjective nature of Q-method interpretation it was decided that taking forward two factors for analysis was most appropriate.

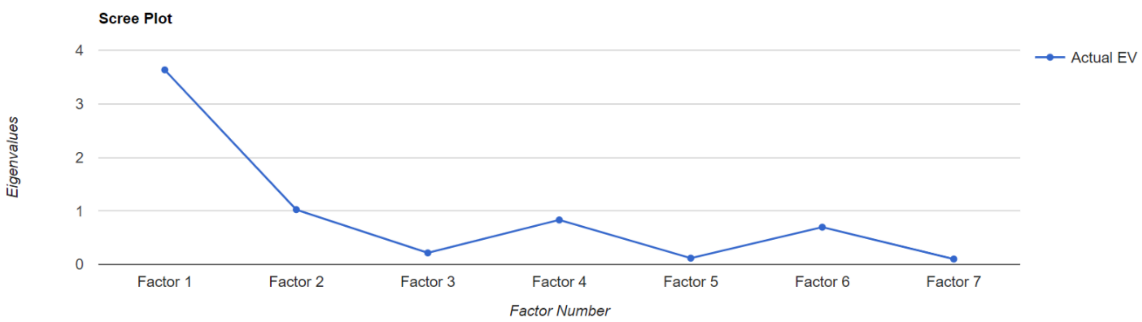

Figure 5.2: A scree plot was used, alongside the Kaiser-Guttman criteria, to determine how many factors to extract. The use of the scree plot helped to separate potentially important factors from those that were not. The scree plot showed a clear point of inflexion at Factor 2. Factors 1 and 2 were taken forward for analysis.

The two factors explained 33% of the study variance (Table 5.3).

Table 5.3: The eigenvalues and percentage of explained variance for Factors One and Two. Factors with eigenvalues >1 were extracted.

	Factor 1	Factor 2
Eigenvalue	3.63	1.03
% Explained Variance	26	7
Cumulative % Explained Variance	26	33

Twelve of the 14 Q-sorts loaded significantly onto the two factors (Table 5.4). The sorts by F11 and N07 were non-significant sorts, meaning they did not load significantly onto either of the factors. Positive, significantly loading sorts were used to derive factor scores and z-scores for each statement (Appendix 5). Distinguishing statements for each factor were identified before each factor was given a title and associated interpretation.

Table 5.4: Factor matrix with rotated factor loadings for 14 sorts in a Q-method study of stakeholder perspectives of HCC intervention strategy success. The flagging process was automated and conducted in PQMethod.

	Rotated Factor Matrix	
Q-sort	**1**	**2**
N01	0.4273*	0.0573
F11	0.2219	-0.2215
F14	0.5461*	0.5193
F15	0.0381	0.3462*
F03	0.2251	0.3882*
N08	0.4559*	0.4408
N07	0.2550	0.2025
N04	0.5637*	0.3486
F21	0.4540	0.6408*
N03	0.8734*	-0.0149
F09	0.1924	0.6509*
N11	0.3386*	0.1917
F05	-0.0684	0.3834*
N09	0.6275*	0.0046
* indicates sorts that load onto Factors 1 and 2.		

5.3.1 Factor interpretation

A composite Q-sort was created for each factor using the factor array scores, this showed the arrangement of statements in a way that was most representative of each factor (Figures 5.3 and 5.4). The original grounded theory interviews were also referred to and incorporated into the interpretation process for each sort. Within the factor interpretations reported below, the statement number is represented in brackets, followed by its corresponding score in the factor array in bold.

Factor 1- Long term collaboration

Seven sorts loaded significantly onto Factor 1 and were undertaken by one farmer (F14) and six conservation stakeholders. Participants associated with Factor 1 placed importance on long term measurements of intervention success (8,**5**) that involve collaboration between farmers and conservationists (36,**4**). Achieving success was considered to require a change in attitude whereby changing the attitude of one person towards predators should be considered a success (25, **4**). This group felt strongly that success should be measured by testing different methods and a control with no mitigation, and then comparing the two to determine which is best (5,**3**). This suggests that an interdisciplinary approach is needed to measure success through a combination of robust trials and attitudinal changes.

Factor 1

					35					
				31	33	26				
			32	21	24	19	34			
		20	22	15	18	17	28	27		
	29	12	13	11	9	3	23	16	36	
30	14	2	4	10	7	1	6	5	25	8
-5	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**

Least Agree ← → Most Agree

Figure 5.3: Composite Q-sort for Factor 1. The composite sort was generated using the factor array scores and presents a summarised viewpoint of all participants loading to Factor 1. The sort is representative of an ideal sort for Factor 1 participants. The composite sort helped to identify perspective features as well as areas of consensus and disagreement.

Factor 2- Financial Benefits

Five sorts loaded significantly onto Factor 2, all of which were undertaken by farmers. In this factor, economic considerations were regarded as the most important aspect of determining success. The priority for this stakeholder group was using interventions where the cost of using and maintaining the mitigation method was lower than savings or other benefits provided (23,**5**). Success was considered easier to achieve when financial resources were not a barrier, and it was felt that those without enough money would ultimately 'lose' against predators (22,**2***). Success needs to be measured long term (8,**4**) with successful methods being those which deter predators from coming near to livestock (21,**3***). Despite a strong feeling that farmers and conservationists determine success

Factor 2

					36					
				35	27	28				
			29	33	25	26	24			
		34	13	19	15	17	22	21		
	20	32	12	18	9	4	16	2	31	
30	14	11	10	7	5	3	6	1	8	23
-5	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**

Least Agree ← → Most Agree

in different ways (31,**4***), involving collaboration between the groups was not ranked highly (36,**0**) and may be indicative of underlying human-human conflict.

Figure 5.4: Composite Q-sort for Factor 2. The composite sort was generated using the factor array scores and present a summarised viewpoint of all participants loading to Factor 2. The sort is representative of an ideal sort for Factor 2 participants. The composite sort helped to identify perspective features as well as areas of consensus and disagreement.

Using factor z-scores, areas of consensus and disagreement were identified. Areas of consensus typically focused on being able to reduce livestock losses with intervention use, but without guarantee of preventing all losses (Table 5.5).

Table 5.5: Consensus statements for the study; statements with the smallest variance across factor z-scores (-5 to +5) whose rankings did not distinguish between the factors. All consensus statements listed were non-significant at P>0.5. Consensus statements were used to identify areas of agreement between Factors 1 and 2.

Consensus Statements			
Statement Number	**Statement**	**Factor Array Score: Factor 1**	**Factor Array Score: Factor 2**
14	Success of methods can't be measured, it's just one of those things	-4	-4
16	You can manage losses with mitigation strategies but there's no guarantee they can completely stop problems	3	2
7	Losses before mitigation are often inflated which makes comparing before and after losses difficult	0	-1
20	Success is measured by no predator tracks inside the kraal	-3	-4
3	Success is measured as declining predation as indicated by farmers	1	1

Areas of disagreement generally focused on the importance of livestock loss as a measure of success and the role of collaboration in determining success (Table 5.6.)

Table 5.6: Non-consensus statements. Statements with the largest variance across factor z-scores (-5 to +5) indicating that statements were ranked in positions that were different between Factors 1 and 2 and may be indicative of areas of disagreement between the factors.

Areas of Disagreement			
Statement Number	**Statement**	**Factor Array Score: Factor 1**	**Factor Array Score: Factor 2**
2	No livestock losses is the main measurement of success	-3	3
34	Farmers expect mitigation placed by conservationists to work by stopping all livestock loss to predators	2	-3
36	Success is best measured by collaboration between farmers and conservationists	4	0
31	Farmers and conservationists determine success in different ways	-1	4
22	Success is easier to achieve with money, if you don't have money you will lose against predators	-2	2
5	Success is measured by testing different methods and a control with no mitigation then comparing which is best	3	0
25	Success is changing the attitude of one person towards predators	4	0

5.3.2 Exit survey responses

Non-compulsory exit survey questions provided participants the opportunity to suggest other means or considerations for measuring intervention success. One farmer and four conservation stakeholders suggested additional ways to measure success (Table 5.7).

Table 5.7: Additional means of measuring success suggested by participants (via an open question at the end of the Q-sort survey, n=5).

Participant ID	Is there anything you think is important for measuring mitigation success that was not covered by the statements?
N01	We need to get more well-known individuals, exposure and investors involved. The truth needs to be more transparent with evidence that needs to be shared without the worry of what might happen. Act now!
N03	Success can also be determined by measuring the impact of mitigation methods on the ecosystem and environment where livestock is.
N04	Livestock loss cost vs the overall cost of the mitigation methods.
N08	Ongoing interaction with affected farmers and communities. Immediate and rapid response to a problem that has occurred is vital. The mitigation officer personal experience and level of understanding, culture of affected farmers. In a lot of instances, an open mind needs to be maintained with "old school" farmers.
F15	The amount of predators that are being killed is not taken into account because the farmers do not talk about it, only about the livestock that are being lost.

5.4 Discussion

Q-method provides a means of characterising human subjectivity and has recently been used by various researchers to understand subjectivities relevant to conservation policies (Rastogi *et al.,* 2013; Zabala, Sandbrook and Mukherjee, 2018; Bavin *et al.,* 2020). Here, a Q-method study was conducted to generate stakeholder-endorsed recommendations as to how to measure success in intervention strategies designed to increase HCC. It is necessary to understand the perspectives of stakeholders to effectively evaluate interventions aiming to increase HCC and determine if desired aims have indeed been achieved. Q-methodology is well-suited to this need (Mazur and Asah, 2013) and its use here highlighted different viewpoints on the topic of intervention success and revealed areas of consensus and disparity in perspectives. With the exception of three individuals, each stakeholder group (i.e., farmers and conservationists (both NGO and PAA workers)) aligned to a distinct factor. Each factor represented a different definition of success and had distinct priorities in terms of what was important in measuring and contributing to intervention success. Factor 1 was characterised by sorts favouring long term, collaborative measures, whilst economic benefits were the most important determinant of success in sorts loading onto Factor 2.

Participants of Factor 1 (conservationists and one farmer) identified long-term measures involving collaboration between conservationists and farmers as the most important measures of intervention success. Collaboration has been recommended in many studies of intervention effectiveness; whereby livestock owners, researchers and conservation managers each have an important role to play in the testing and evaluation of different interventions (van Eeden, Eklund, *et al.,* 2018). The high ranking of collaboration in Factor 1 follows findings from the interviews conducted for this study in which it was identified that whilst conservationists view collaboration as vital, farmers were more likely to trust the opinions of other farmers when determining intervention success (see chapter 3A; Lucas *et al.,* 2022). Collaboration is typically considered important as a mechanism for development and/or implementation, here it is being regarded as a measure of success which suggests that achieving HCC to these stakeholders is about coexistence between different people as much as it is between people and wildlife. The need for collaboration recognises the complexity of achieving HCC goals and the importance of engaging with different stakeholders, as has been acknowledged previously (e.g., Redpath *et al.,* 2017). Alongside collaboration, the importance placed on needing long term measures suggests that there is an awareness that success can fluctuate overtime and is often dependent on consistent use and continued maintenance which requires users' involvement and responsibility over the long term (Weise *et al.,* 2018). Conducting such long-term measures would require trust and collaboration between stakeholders hence it follows that both were ranked highly.

Additionally, participants of Factor 1 favoured a more scientific approach to measuring success, i.e., testing different intervention methods alongside a control to determine which method is most successful. However, this approach was not ranked highly in Factor 2 (comprised entirely of farmers). Conservationists have argued that in order to determine success, equal treatment and control samples should be deployed to produce estimates of intervention effectiveness according to relative risk and magnitude of change (Khorozyan, 2020). Such controlled experiments to test livestock protection interventions are rare (van Eeden, Eklund, *et al.,* 2018) but are feasible; for example, see Ohrens *et al.,* (2019). However, conducting such controlled trials is often unrealistic in many field scenarios and may not suit the needs of farmers, particularly if scientific evidence is not their main source of information (Madsen *et al.,* 2020). Ethical considerations, such as leaving a farm unprotected during controlled experiments, also limit the viability of experimental designs (van Eeden, Eklund, *et al.,* 2018). The conservation stakeholders in this study may have been more inclined to rank controlled studies highly due to their backgrounds and training in the scientific method, as seen in the demographic data, the result of which meant they may be more likely to favour scientific practises.

For Factor 2 participants (all farmers), the most important component of success was cost. This comprises many elements including labour, time, tools, equipment, consumables and overheads. In South Africa, livestock predation has been estimated to cost in excess of ZAR1 billion per year (GBP 49 million) and has complex social, economic and ecological drivers and consequences (Kerley *et al.,* 2017). This was exemplified by a participant during the previous interviews:

"*The whole economy is shot- our labour costs going through the roof, Eskom [electricity] going through the roof so really, we battle to survive, so you start, you cannot lose a calf because you, you, that ZAR 6000/7000 is something you really need."* F20

In this study, cost was a major factor in determining perceptions of specific intervention strategies with, for example, increasing labour costs preventing the use of herders (see chapter 3B). The perceived costs of intervention use can therefore create real or perceived barriers to intervention use (Nilsson, Fielding and Dean, 2019). Whether interventions are considered affordable will also depend on indirect and opportunistic costs as well as the financial situation of the individual. Thus, farmer perception of success is not just shaped by costs of livestock loss and intervention use but the wider economic environment. The importance of economics in determining success suggests that prioritising cost-effective interventions should help achieve conservation goals (Cook *et al.,* 2017; Pienkowski *et al.,* 2021). It is likely that Factor 2 participants were much more concerned about costs than conservation stakeholders comprising the majority of Factor 1 because the maintenance costs of interventions are usually carried by farmers. Additionally, the costs of losses are entirely borne by farmers and therefore spending money on top of losses may make financial considerations more important to farmers.

Despite this, it should be acknowledged that the costs of interventions to conservation NGOs can also be substantial (e.g., cost of livestock guardian dog (LGD) placements, first year care and on-going monitoring and support (Rust, Whitehouse-Tedd and MacMillan, 2013)). Regardless, if a strategy fails, the farmers will invariably suffer financially, - particularly if they are dependent on the farm and livestock as their primary source of income (Chapter 2.3.2). In contrast, failure of a strategy implemented or supported by an NGO is less likely to cause personal financial harm to the NGO staff. With the exception of complete or substantial withdrawal of funding, NGOs associated with failed intervention strategies may instead suffer in terms of reputation or donor funding whilst individual salaries are less likely to be immediately impacted. Personal finances impact the ability of landowners to manage their land for biodiversity (Selinske *et al.,* 2018) and costs of intervention implementation and/or maintenance can prevent their use or acceptance (Gunaryadi, Sugiyo and Hedges, 2017). Therefore, interventions can be potentially effective, but would not be classed as successful if they were unused because of financial constraints (Khorozyan and Waltert, 2019). For example, herding is not practised in areas where the costs of hiring a shepherd do not offset the costs of livestock loss (Breitenmoser *et al.,* 2005). It is therefore logical that, in general, interventions that are regarded as both financially viable and that improve (or at least maintain/secure) livestock outcomes/productivity will more likely be considered successful by farmers.

Moreover, in many fields, particularly those focused on profit or public accountability, the importance of accurately accounting for costs in a transparent manner has been recognised (Pienkowski *et al.,* 2021). Good cost reporting summarises financial data so they can be confidently and transparently used in economic evaluations (i.e., assessment of costs relative to benefits) and for decision support (Drummond *et al.,* 2015). However, the views expressed here suggest that HCC intervention implementation may be lacking in financial accountability, although it is possible that financial reporting is not reaching those most at financial risk (i.e., the farmers). Consequently, transparency regarding setup and maintenance costs prior to intervention implementation offers stakeholders informed decision making tools and can also be used by advocates of the method to identify early on when something is not going to be economically viable for the end-user.

F14 was the only farmer participant to load to Factor 1. During the interviews (see chapter 2 and 3A), F14 emerged as one of the more proactive farmers who considered coexistence between livestock farmers and carnivores to be possible, particularly with the use of appropriate intervention strategies. This participant demonstrated strong knowledge about carnivore behaviour and the potential consequences of using lethal control methods.

"*If I go out and I shoot the male, the dominant male leopard on this farm I can promise you, within a month there's four young males on this farm trying to get this territory for them so you can't solve the problem by killing them, you can't. In fact, I think you're going to cause yourself more damage than which you had." F14*

This comprehensive understanding of carnivore behaviour (i.e., territoriality and the vacuum effect (du Toit, Cross and Valeix, 2017)) may contribute to separating this participants responses from those of the other farmers and aligning their perspective more with the conservation stakeholders in Factor 1. Furthermore, F14 farms multi-functional property in close vicinity to active conservation programmes making them likely to have more interaction with researchers and conservation orientated stakeholders than the majority of farmer participants. More regular exposure to conservation ideas and practices may subsequently impact on perceptions of intervention success and coexistence. Additionally, F14 considered it the responsibility of a farmer to cover the costs of protecting and managing livestock on a daily basis. In this regard, the participant made the following distinction:

"*Actually, I think you get livestock farmers and then you get people they just have livestock, there's a massive difference… I see that's where the difference comes in, you've got that guy where's he got livestock, he actually feels nothing for his livestock as well so why's he going to feel anything for predators. Then you get the guy which actually cares for his farm and for what he's farming with and* *he's willing to make a plan cause he knows it's not a viable way to keep your goats safe is to kill everything on the farm cause it doesn't work, you're going to shoot one now and there's a couple of new ones going to come in. You'll never win the fight*." F14

In this instance, how livestock are perceived by the farmer and the farming practises utilised appeared to influence knowledge of intervention strategies, their subsequent use, and perceptions of their success. Such beliefs may further explain why this farmer aligned more with Factor 1 than other farmer perceptions.

5.4.1 Areas of agreement

Whilst there were various methods reported for measuring success, stakeholders agreed that fundamentally success can be measured, and subsequently it should be possible to establish common measures of intervention success. Furthermore, it was agreed that losses can be managed with the use of intervention strategies but there is no guarantee that their use can completely stop depredation or other damages. Acknowledging that losses may still occur is a good starting point for building (or managing) shared expectations of success between stakeholders. Whilst Factors 1 and 2 aligned via a recognition that preventing losses entirely cannot be guaranteed, it emerged that Factor 1 participants (predominantly conservationists) perceived farmers to expect depredation to cease entirely after mitigation strategies were implemented by conservationists. However, participants of Factor 2 (all farmers) strongly disagreed with this. Conservation stakeholders therefore appear to perceive farmers to have more extreme expectations of intervention effectiveness, potentially inferring zero tolerance towards depredation, which is at odds with the more pragmatic expectation expressed by farmers themselves (i.e., that some level of depredation may be inevitable). Although previous research has demonstrated that farming stakeholders can be willing to accept damage caused by wildlife up to a threshold (Frank, 2016), conservation stakeholders in the current study appear to hold an important misperception of farmers which could manifest as inter-stakeholder conflict. As such, discussing and agreeing acceptable losses is likely to improve mutual understanding and may aid in developing common expectations and units of measurement or a threshold for success to be considered achieved. To this end, models have been developed to better understand acceptable levels of loss and carnivore population numbers. For example, the Wildlife Acceptance Capacity model indicates the maximum wildlife population level in an area that is acceptable and has been used to help understand tolerance levels (Bruskotter *et al.,* 2015; Western *et al.,* 2019).

Misunderstanding between stakeholders can stem from unrealistic expectations associated with the degree to which interventions are expected to work (Khorozyan *et al.,* 2020). Conservation stakeholders should be wary of creating or supporting expectations that are not realistic (Nyumba *et* *al.,* 2018) and should not have unrealistic expectations themselves. Additionally, conservationists should recognise that they are not neutral and have their own interests and goals which may clash with those of other stakeholders (Brittain *et al.,* 2020). It was found (see chapter 3A, Lucas *et al.,* 2022), that NGO participants felt that farmers should be willing to lose more stock than farmers reported they could accept to lose. Whilst this could help to explain why conservationists in this current study thought farmers were less tolerant of losses than they were, it should be recognised that no numbers of acceptable loss were used in the Q-method and differences may arise in specific acceptable numbers of losses for each farmer. The potential for differences indicates a possible area of discord between stakeholder groups as to acceptable numbers of loss and further emphasises the importance of establishing shared expectations of interventions prior to implementation. Understanding acceptance levels will subsequently help to identify potential conflict over intervention success and prevent misunderstandings between groups holding divergent views on intervention acceptability (Redpath, Bhatia and Young, 2015; Eklund, Flykt, *et al.,* 2020).

Participants from all stakeholder groups agreed that success is likely to take some time to see and therefore success may develop overtime e.g., LGD puppies require training on placement and are not expected to work immediately (Marker *et al.,* 2020) . As such, long term measures of success may be particularly important since human-carnivore interactions are dynamic, and the nature of interactions can fluctuate over time (Young *et al.,* 2016). Similarly, people's perceptions of interventions are shaped by multiple factors and may also change (Bennett, 2016). For example, the effectiveness of some intervention strategies can reduce or improve over time with refined use or training. Consequently, changing perceptions may reflect changes in effectiveness (Blackwell *et al.,* 2016) but may be subject to variable lag time. Evaluations of interventions should therefore consider the potential for habituation by target wildlife (Khorozyan *et al.,* 2020), or other causes of changed effectiveness. Where reductions in efficacy are identified, modifications may be made to the intervention to prevent habituation or other causes of decreased effectiveness. Long term measures of success may also subsequently highlight the need for changes to the intervention as well as the need for adaptability and responsiveness. It should also be considered whether changes in circumstances and context can lead to changes in perceptions, independently of realised intervention efficacy alone. Furthermore, there is a need to manage the expectations of users regarding the timeframe required post-implementation before impacts are measurable and how much time a strategy may need to be used before desired outcomes are achieved.

There was consensus between participants aligning with Factors 1 and 2 that losses before implementation of any mitigation can be inflated, which makes comparing before and after losses in recall-reliant studies difficult. Whilst there was consensus, the statement was not ranked highly. However, it may suggest that reliance on recall to determine previous losses is not considered accurate by any stakeholder, particularly over long periods of time. It may also reflect that comparing losses is difficult when situations may have changed, such that before-after comparisons may be compromised. Importantly, errors in loss estimations can occur for several reasons including over-estimation in order to receive financial incentives from compensation schemes (Bulte and Rondeau, 2005), using unreliable methods of counting losses or assigning cause, poor record keeping, or variable approaches to quantifying losses. For example, it has been observed that many Maasai could not express livestock loss quantitatively and alternative, culturally appropriate methods were developed to collect efficient data on perceived losses (Hazzah *et al.,* 2009) . In the current study, farmers reported measuring change in livestock loss in a number of ways e.g., numerical difference between losses before and after interventions, reduced number of incidents of loss or injury and increased percentage of livestock successfully raised from birth (see chapter 3A, Lucas *et al.,* 2022). The idea that losses can be erroneously or variably determined follows other studies which have found large carnivores to be incorrectly identified as the cause of livestock loss therefore causing estimates of predation to be inflated (Gebresenbet *et al.,* 2018). As such, the use of farmer recall to determine intervention success has been criticised (van Eeden, Eklund, *et al.,* 2018; Ohrens, Santiago-Ávila and Treves, 2019). This follows the perceptions of Factor 1 participants who did not rank livestock loss as the main measure of success highly.

5.4.2 Areas of disagreement

The most apparent topic of disagreement between participants of Factors 1 and 2 was over the absence of livestock losses as being the main measure of success. This statement was placed highly in Factor 2, the farmer factor, but not by Factor 1 (comprised predominantly of conservationists). Herein, farmers placed greater importance on reduced livestock loss as being the main measure of intervention success. In contrast, conservation stakeholders were less likely to consider this the most important measure of success and instead favoured tests of the chosen method alongside a control to determine success. As a consequence, it is likely that the extent of success perceived for an intervention will also vary among stakeholders. Reviews such as those by Eklund *et al.,* (2017) and van Eeden *et al.,* (2018) have previously demonstrated the diverse interpretations and evidence of effectiveness used in this field and highlighted the potential for these differences to lead to antagonism between stakeholder groups. Different stakeholders have different perspectives on the roles that functional effectiveness may have in achieving HCC goals (Ohrens, Santiago-Ávila and Treves, 2019). Interventions that are considered functionally effective as measured by scientific investigation (by inference also receiving more attention in the scientific literature), may concurrently be considered failures by farmers if they fail to meet their threshold of acceptable effectiveness (Denninger Snyder and Rentsch, 2020). Since user-based evaluations are often less widely disseminated, especially in regards formal avenues of reporting such as the scientific and grey literature, recommendations for future intervention use derived from the literature risk exacerbating farmer-conservationist discord. Furthermore, scientific evidence of effectiveness may not address conflicts between conservation and farmer interests (Redpath, Bhatia and Young, 2015).

If reductions in or the absence of livestock loss is considered an important measure of success by farmers, then it is likely to influence behaviour changes and tolerance towards carnivores. In this instance, conservationists advocating an intervention as effective based on controlled experiments, may be meaningless to users, or (at worst) considered ineffective when measured according to the farmer's unit of success. Furthermore, participants associated with Factor 2 strongly agreed that farmers and conservationists determine success in different ways, whilst Factor 1 disagreed with this statement. This suggests that farmers are aware of their different methods of measuring success (as supported by the varying ranking of the importance of livestock loss between the two stakeholder groups), but there is a lack of awareness of this difference among conservationists. Being unaware of other stakeholders' perceptions, or failing to recognise that inter-stakeholder differences exist, may erode trust or pose a barrier to relationship building between stakeholder groups, especially when advocating for different strategies. Trust and meaningful engagement between stakeholder groups is deemed fundamental to achieving HCC goals (Waters *et al.,* 2018).

The farmer who completed the exit survey suggested that recording the number of predators killed should be used as measure of success since farmers do not talk about this and only discuss numbers of livestock that are being lost. It is interesting to note that this was mentioned by a farmer participant as it suggests that lethal control of carnivores occurs and can be easily hidden by farmers as they simply do not talk about it. Establishing the amount of lethal control occurring in an area is important and vital to understand if reduced persecution is a primary goal of the intervention strategy. However, obtaining such information is likely to be difficult and requires a substantial amount of trust between farmers and conservationists. Increasingly, conservationists seek reliable information from the community being studied about people's behaviour, including illegal or sensitive topics (Cinner, 2018; Ibbett, Jones and St John, 2021). Specialised questioning techniques such as the Unmatched Count Technique (UCT) (Droitcour *et al.,* 1991) and Randomised Response Techniques (RRTs) (Warner, 1965) have been developed to overcome social desirability biases (Ibbett, Jones and St John, 2021). RRT has been used to investigate many issues relating to conservation including illegal persecution of wildlife, breaches of fishing regulations, consumption of wildlife and illegal use of natural resources from protected areas (Ibbett, Jones and St John, 2021). RRT has been used to investigate illegal behaviours towards carnivores in South Africa (St John *et al.,* 2012) and such techniques could therefore be added to intervention evaluations to better understand behaviour changes.

The need for collaboration between farmers and conservationists in order to determine success was considered important by Factor 1 participants but not placed highly by those in Factor 2. Whilst it is often recommended that farmer input is needed to determine success, Gray *et al.,* (2020) found that few studies involved local communities in the research process beyond passive data collection as research subjects and such stakeholders are rarely included as co-authors on resultant publications. However, farmers do not typically use academic research in their decision-making processes surrounding intervention strategy use (Volski *et al.,* 2021). Rather, farmers are more likely to make decisions based on word of mouth from other livestock farmers (Wilkes *et al.,* 2018; Volski *et al.,* 2021; Lucas *et al.,* 2022). This reveals an area for potential disagreement between stakeholder groups and could indicate that farmers do not rely on the opinions, or cooperation, of conservationists to determine intervention success. Moreover, it indicates a lack of trust in conservationists by farmers.

In the exit survey, one conservation stakeholder (N017) specified that success requires ongoing interaction and collaboration with farmers and communities affected by negative interactions with carnivores. This suggests that when a problem does occur, and is reported, there needs to be an immediate and rapid response from conservation stakeholders. Such a response is likely to maintain the relationship and build trust between parties, which is necessary for collaboration. N017 also highlighted that conservation stakeholders need to have an understanding of the culture of affected farmers and in some cases will need to keep an open mind, particularly with farmers using more traditional farming techniques. These comments draw on parallels with the importance of collaboration in determining success that emerged in Factor 1. It also demonstrates some awareness of the perceptions held by farmers and potential differences between stakeholder groups.

Given that much of the large carnivore range in southern Africa lies on private land, collaboration with farmers is subsequently vital to the success of conservation programmes and survival of species such as cheetah (*Acinonyx jubatus*) (Durant *et al.,* 2017) and leopard (*Panthera pardus*) (Williams *et al.,* 2017). Without collaboration, conservation stakeholders would not be able to achieve their goals and as a result have a vested interest in working with farmers. In contrast, farmers are not reliant on conservationists for their livelihoods or income. This difference in the perceived importance of collaboration links to disagreements in the importance of livestock loss as a measure of success; if farmers determine success independently using their own metrics, collaboration with conservationists becomes unnecessary, particularly if they have financially invested in the intervention.

In addition, changing attitude as a sign of success was ranked highly by participants of Factor 1. For conservationists, intervention success is not just about reduction in livestock loss but also changes in attitude and behaviour towards carnivores. In contrast, farmers were more likely to focus on the livestock protection aspect of interventions which links with their reported focus on economic considerations. It therefore follows that if change in attitude is an important measure of success, collaboration is necessary.

5.4.3 Non-significant sorts

Two sorts did not load significantly to either Factor. The sort by F11 did not place statements about finances highly, which contrasted with the perceptions of other farmers who considered the costs of mitigation as very important in determining intervention success. Rather, F11 felt that success is difficult to measure as it is not possible to know what losses would be without use of the intervention. This aligns with a more scientific approach to determine success whereby controlled trials would be needed and contrasts with other farmer perceptions. However, F11 did not rank long-term, collaborative measures highly which explains why they did not load onto Factor 1 despite taking a more scientific approach to measuring success. Additionally, F11 felt the use of camera traps can help to show that predators have not threatened livestock. This participant was not reliant on livestock for income, rather crop production was the main source of their income, and was therefore more accepting of losses in comparison with other farmers (see chapter 2).

Diversification of income has previously been associated with positive perceptions and attitudes towards carnivores (Dickman, 2010). As such, attitudes to carnivores may be shaped by loss relative to overall wealth, rather than absolute losses (Inskip and Zimmermann, 2009). Likewise, perceptions of intervention success may be influenced by source of income, rather than income itself. Subsequently, the consequences of livestock loss were likely less significant or far reaching for this participant with multiple income sources, compared with other farmer stakeholders surveyed who were more dependent on livestock for income. This relative independence from livestock-derived income may therefore explain this participant's apparent misalignment with other farming stakeholders.

F11 also had one of the largest properties and smallest herds of livestock in the study (chapter 2). The herd was considered easy to protect with the use of electric fenced kraals near to occupied buildings, as discussed by the participant during previous interviews (Chapter 3A.4.2):

"*But you have to keep in mind er, it's all according to how much game you've got or how much cattle you got… this is a small quantity so they can stay on a small area that's electrified, if it's a big area the whole pictures changing ah you can't do that ja….Smaller quantities ja that's controllable." F11*

It has previously been found that those with larger farms are less likely to view carnivores as a threat to livestock (Fort *et al.,* 2018). Here, perception of success may have been influenced by farm and herd size which distinguished this participant from other farmers. In comparison, the other farmers had larger herds on smaller farms and subsequently considered livestock loss harder to manage. Furthermore, the electric fences were initially invested in for the purpose of preventing baboon crop foraging and have subsequently been utilised for livestock.

"*The electric fences were originally for the baboons when we were still planting tomatoes there so everything was in place for the tomatoes but that whole field is now in a five-year resting period…so I put the cattle there and it fits me like a glove." F11*

The use and cost of electric fences were therefore considered part of running the farm as whole, rather than a specific investment for protecting livestock from predation. This may contrast with other farmers who invested in interventions solely for livestock protection. For this reason, it is likely that perceptions of success are influenced by the context in which the strategy was obtained (Eklund *et al.,* 2017).

Conservation stakeholder N07 did not load significantly to either of the factors. This sort placed importance on an overall reduction in interactions between livestock and predators. Whilst this partially aligns to the idea of reducing livestock losses, this may suggest that they were focused on reducing any form of interaction between carnivores and predators, not just those resulting in loss. Additionally, it was expressed that success is difficult to measure as it is not possible to compare what losses would be without interventions in place. Whilst this shows some common ground with other conservation stakeholders and the importance of scientific experiments to determine cause and effect, it suggests that N07 was either unaware of the idea of a "control" or did not consider that conducting controlled trials were feasible in the circumstances. N07 felt that success cannot be guaranteed when strategies are put in place by conservationists.

"*They'll expect obviously no livestock to get killed erm but then if we go, if there has been a complaint we'll go down there and see that basically they haven't maintained their boma for the last year or for the last two years erm so ja, so they're definitely from the, I think they're expected to work a 100 % erm and that's where it's really important the education part of it basically ongoing and continual education."* N07

Such perspective may be indicative of a realist perspective where the participant felt that success is dependent on many factors including maintenance which is often out of the control of conservationists. However, it may also reflect a lack of trust in farmers to utilise interventions effectively.

5.4.4 Limitations

When using Q-method, it is not possible to determine how the different perspectives are distributed among the broader population (ten Klooster, Visser and de Jong, 2008). Rather, by selecting the participants for the Q-sort using evidence of each person's understanding and experience of the topic, it was possible to represent diversity within and between stakeholder groups. Therefore, the results presented here reflect the situation for these stakeholder groups within the study region. Whilst the results from this study cannot be generalised and should not be used to make assumptions about stakeholder groups not represented here, they could be applied (with a degree of caution) to similar contexts within Southern Africa, or used as a starting point to understanding or investigating other scenarios.

It should be highlighted here that the analysis of Q-method surveys is somewhat subjective; in factor analysis there are usually several potentially acceptable solutions (Watts and Stenner, 2012), and the researcher plays a role in deciding how many factors to take forward and their interpretation. In the study, it was decided (based on eigenvalues and interpretation of the scree plot), that two factors made the most analytical sense. Factor 1 is strongly loaded whilst there is less support for Factor 2. It is usual in factor analysis that the first factor extracted will account for the largest amount of study variance with successive factors steadily decreasing in size (Watts and Stenner, 2012). This is due to the factor analysis process used in PQMethod. In Q-method, the first factor represents sorts with the most common ground. As such, extraction removes the largest portion of shared perceptions, PQMethod continues analysis by searching the residual correlation matrix for any further portions of common variance present in the data (Watts and Stenner, 2012). If it finds one, this will become Factor 2. A factor loading is again calculated for each individual Q sort relative to this new factor and the factor is again extracted from the data, leaving a correlation matrix of second residuals. If therefore follows that Factor 2 (and any other subsequent factors) will have a factor loading that is relative to the remaining data (i.e., without the sorts loading to Factor 1).

It is common to collect qualitative data throughout the Q-sort process by encouraging participants to talk about their decision-making process. This qualitative data can play a role in interpretation and help create a fuller understanding of why the participants sorted the statements in the way they did. As the survey was conducted online, these additional data could not be collected and therefore it is not possible to fully understand the thinking process behind statement positioning. However, it was possible to partially overcome this lack of dialogue during the Q-sort by having a good understanding of each of the participants viewpoints as a result of prior interactions and interviews (chapter 2, 3A and 3B); data from these interviews were used to inform the Q-sort interpretation.

Furthermore, it was unclear to the researcher how much each participant understood about the process. Whilst five participants described the Q-sort process as interesting, five stated that they found the survey difficult and wanted to put more statements onto the agree side than the distribution grid allowed for. This indicates that some participants did not fully understand that placing a statement towards the disagree end did not mean they disagreed with the statement but only that they agreed with that statement less than higher ranked statements. However, it should also be noted that the ability to conduct the Q-method survey online made conducting the survey within Covid-19 restrictions in South Africa possible where otherwise it would not have been; therefore, the online platform offers an important tool for researchers and practitioners working with remote or spatially-distanced stakeholders.

The survey was conducted in English; although English was not the first language for all participants, it was the common language among all stakeholders and therefore deemed most appropriate. One farmer participant gave feedback that they found some of the language '*a bit too high for a farmer'* and expressed that some terms could be interpreted in different ways.

The exit survey at the end of the Q-sort provided the opportunity to suggest other means of measuring intervention success. For example, it was also suggested that success can be determined by measuring the impact of mitigation methods on the ecosystem and environment where livestock is farmed (N03) and that success should also take into account the cost of livestock loss versus the overall cost of using the intervention strategy (N04). Had it been feasible to conduct a group workshop prior to conducting the Q-method, such statements may have been revealed and incorporated into the Q-sort.

5.5 Conclusions

A number of studies have highlighted the importance of understanding stakeholder values in HCC studies (e.g., Manfredo and Dayer, 2004; Dickman, 2010; Lute *et al.,* 2016). However, these tend to focus on the views of one specific set of stakeholders. Our findings highlight the importance of exploring the values and perceptions of different stakeholder groups involved in HCC scenarios. Whilst exploring and acknowledging different values does not change values or remove areas of disagreement, it helps to expose different viewpoints which can subsequently be used to develop compromises and solutions through discussion (St John *et al.,* 2018).

Determining whether an HCC intervention is successful depends on many factors (Pienkowski *et al.,* 2021). The emergent perspectives indicate that overall success is comprised of many measures. The results of this Q-method study show that farmers are foremost interested in economic measures and the financial viability of interventions. As a result, the costs (implementation and running) of interventions need to be transparent and readily available prior to intervention implementation. This is particularly important if the intervention is recommended or provided by conservationists. If finance is a key determinant of strategy success for farmers, arguably the role of conservationists is then to ensure that any intervention they advocate is financially viable for end-users, rather than to determine their own measures of success that may not be valuable to users. As such, it may be essential to have more than one set of success measures; a primary measure that is common to all stakeholders and other measures that can be more specific to each stakeholder group.

The main topics of disagreement bring to light areas of potential human-human conflict which is often a key concern in many HCC scenarios and typically a root cause of contention (Frank, Glikman and Marchini, 2019). The use of Q-sort here proved valuable in highlighting multiple areas in which human-human conflict could arise when evaluating the success of intervention strategies, e.g., differing expectations and the role of collaboration in achieving success. Whilst consensus is not always appropriate, or results in longer processes (Peterson, Peterson and Peterson, 2005), building areas of consensus and understanding divergent viewpoints may foster greater trust in scientific processes among farming stakeholders, on whom conservation success largely depends (Lute *et al.,* 2018). The areas of consensus identified here, e.g., acknowledgement that interventions are unlikely to stop all losses, could be used as a starting point to demonstrate that participants have a shared understanding and provide neutral ground from which to develop a discussion.

The use of Q-method has enabled the development of a final set of stakeholder-informed and endorsed recommendations to determine intervention success in the context of HCC scenarios. To measure intervention success in a meaningful manner, relevant to both farmer and conservation stakeholders, the following activities are required:

- Clear transparency of set-up, maintenance, and long-term costs to determine whether interventions will be financially viable to users.
- Development of shared units of measurement and criteria for determining success, prior to implementation.
- Establishment between interested stakeholders of the threshold of acceptable levels of livestock loss and recognition that not all losses can be stopped to ensure that expectations of interventions can be met.
- Long-term monitoring of intervention efficacy and context to determine whether changes to the intervention are required.

- Development of greater social trust and communication to facilitate improved collaboration between stakeholders to ensure information regarding intervention use is openly shared.

Future studies should put into effect these recommendations prior to strategy implementation to ensure that the needs of all stakeholders are met, and HCC goals can be achieved.

Chapter 6: Discussion

6.1 Synopsis

Carnivores are apex predators that drive the structure and function of biological communities in diverse ecosystems (Holland, Larson and Powell, 2018). Across the world, the presence of carnivores helps to regulate ecosystems through direct and indirect pathways. However, increasing human population density, habitat loss and fragmentation, reduced prey and elevated rates of conflict (Schuette, Creel and Christianson, 2013), mean that carnivore species have suffered substantial population declines and geographic range contraction (Ripple *et al.,* 2014). Interactions with carnivores can also have significant consequences for human livelihoods, health, safety and well-being (Nyhus, 2016; Baynham-Herd *et al.,* 2018). People living alongside carnivores can experience depredation of domestic livestock, human injury or death and the transmission of zoonotic disease from wildlife to humans and/or livestock (Gebresenbet *et al.,* 2018; Torres, Oliveira and Alves, 2018). Changes in land use and environmental degradation have increased the likelihood of human-carnivore interactions with potentially detrimental outcomes for carnivores, people, or both. Therefore, increasing coexistence between carnivores and communities has become critical to the survival of many carnivore species as well as being vital for human livelihoods and global food security.

Managing interactions between humans and carnivores is regarded globally as a major conservation challenge (Bautista *et al.,* 2019; Chapron *et al.,* 2014; Peterson *et al.,* 2010). The conservation of many carnivore species is challenging due to their large ranges, low densities and negative interactions with people (Bauer, de Longh and Sogbohossou 2010). Carnivores need to be able to persist in human-dominated environments outside of protected areas (Mkonyi *et al.,* 2017; Lute *et al.,* 2018) and, as such, private land plays a vital role in biodiversity conservation (Amit and Jacobson, 2017). Interest in increasing coexistence with carnivores in agricultural landscapes has led to the development of numerous interventions largely designed to reduce livestock depredation (Miller *et al.,* 2016). To date, many evaluations of human-carnivore coexistence (HCC) interventions have have relied solely on measurements of perceived livestock loss before and after strategy implementation (Miller *et al.,* 2016; Eklund *et al.,* 2017; van Eeden, Eklund, *et al.,* 2018), and typically exclude assessment of changes in human behaviour, attitudes or tolerance towards carnivores. However, if interventions aim to increase coexistence through an assumption that reduced livestock loss will reduce persecution of carnivores, measures of success need to consider both biological effectiveness and changes in human behaviour or attitude (van Eeden, Eklund, *et al.,* 2018; Eklund, Johansson, *et al.,* 2020). Studies exploring the drivers of negative human-carnivore interactions acknowledge that social factors shape people's interactions with the environment and that ecological knowledge alone cannot solve conservation issues (Fox *et al.,* 2006; Bekoff and Bexell, 2010; Bennett *et al.,* 2016). Despite growing awareness that interdisciplinary and qualitative approaches are key to better understanding HCC scenarios, stakeholder perceptions and measures of intervention success largely remain undetermined. The use of multidisciplinary mixed method approaches can reveal differences in perspectives among stakeholder groups in HCC contexts (Sutherland *et al.,* 2018). Understanding the various stakeholder perceptions of HCC interventions and success that exist for a conservation initiative facilitates their incorporation into practice and will likely improve intervention engagement. This thesis set out to explore HCC using a multi-stakeholder socio-ecological approach with a particular focus on stakeholder perceptions and measures of success pertaining to interventions designed to increase HCC. By exploring similarities and differences between stakeholder groups, and generating recommendations for future evaluations of intervention success based on stakeholder experience, this thesis addresses an important knowledge gap in HCC.

Using grounded theory interviews and participant observation, chapter 2 explored the factors that shaped stakeholders' relationship with carnivores and how these may impact HCC in the context of the study site and study participants. The inclusion of multiple stakeholder groups revealed previously unconsidered similarities and differences in their perceived drivers and barriers to HCC which were not just related to livestock loss but constructed from multiple socio-cultural, political and economic factors. The implementation of HCC interventions without comprehensive understanding of these factors is likely to result in the failure to achieve desired goals (Anand and Radhakrishna, 2017). Chapter 3A provided an in-depth exploration of participant measures of intervention success and whether coexistence as a concept was considered feasible. It was found that most participants based their measures of success on a reduction in livestock loss. Despite its prevalent use in the scientific literature, concern has been raised over the subjectivity and reliance on recall of this measure (van Eeden *et al.,* 2018; Ohrens, Santiago-Ávila and Treves, 2019; Khorozyan and Waltert, 2021). However, it was relied on heavily by users of HCC interventions suggesting it is likely to influence behaviour and decision-making towards both intervention use and carnivores, and is therefore a valid and functional metric for all stakeholders. Participants were largely in consensus that coexistence relates to humans and wildlife being able to live together. Whilst specific perceptions of coexistence varied, the majority of participants suggested it was attainable with certain caveats. For example, some farmers considered coexistence feasible only if they could make a living from livestock farming. Chapter 3B investigated perceptions of different intervention strategies and the factors that contributed to their perceived success. Perceived success of different interventions was highly individualised and context dependent. The findings showed that understanding which strategies are perceived as successful, as well as the factors that were reported to contribute to success, will enable development and implementation of interventions with the end-user in mind, therefore optimising engagement. In chapter 4, interview and camera trap data regarding carnivore presence, frequency of visits and livestock-carnivore interactions were evaluated concurrently to explore complementary, contrasting and synergistic areas of knowledge. The inclusion of both interview and camera trap data also provided novel insights into how information from different sources can be used by stakeholders to justify their perspectives. Chapter 5 used stakeholder measures of success determined in chapter 3A to conduct a Q-method survey. The use of Q-method revealed that, in general, stakeholder groups (farmers and conservationists) had different priorities regarding the measurement of intervention success, with farmers' foremost interest being economic measures, while conservationists prioritised long-term collaborative measures. Areas of potential human-human conflict were brought to light, whilst areas of identified consensus could be used as a starting point to develop discussion between stakeholder groups. The findings generated throughout this thesis resulted in a final set of stakeholder-informed recommendations to determine intervention success in the context of HCC scenarios.

In this final chapter, I will present a summary of the main research themes and key findings, discussing their implications and potential avenues for further research. I end by suggesting a number of recommendations for evaluating success in HCC scenarios and implications for future research. Stakeholder-derived recommendations for evaluating success were generated and subsequently validated through a Q-method study (chapter 5). These are included here alongside my own original recommendations based on analysis and interpretation of the data.

6.2 Key findings

To best address the research aim, the study used a multi-disciplinary mixed-method approach including participatory observation, semi-structured interviews, participatory mapping, camera trapping and Q-method to engage with multiple stakeholder groups. This approach was used to facilitate the collection of rich socio-cultural data necessary for exploring stakeholder perceptions of HCC intervention scenarios and to understand the factors involved in facilitating coexistence. The inclusion of people's perceptions in conservation studies has grown in recent years due to increasing awareness of the critical role that human dimensions play in achieving conservation goals (Bennett *et al.,* 2017). It has long been recognised that people's perceptions of carnivores are complex and shaped by a multitude of contextual factors including past experience and personal motivations as well as the reports of individuals and social norms (Treves and Karanth, 2003; Bennett *et al.,* 2016; Ballejo, Plaza and Lambertucci, 2020). Perceptions can also be driven by governmental policies which dictate what people can and cannot do in response to livestock-carnivore interactions (Kerley, Wilson and Balfour, 2018). To my knowledge, there are no other studies using an inductive qualitative approach to explore stakeholder perceptions of HCC or of intervention success. In this novel study it emerged that the views of participants were highly individualised and influenced by social, cultural, economic and political experiences. The findings highlight why understanding and making decisions about HCC scenarios can be challenging, as human realities and perceptions vary widely both within and between stakeholder groups (König *et al.,* 2020).

The human-carnivore relationship

The relationship between humans and carnivores has been found to be influenced by a wide range of factors including age, education, wealth, knowledge of carnivores, culture, concern over safety, benefits derived from wildlife, and experience with conservation authorities (Lagendijk and Gusset, 2008; Gebresenbet *et al.,* 2018; Bickley *et al.,* 2019). The participants of this study (farmers, NGO, PAA and tourism stakeholders) were no exception to this and through the grounded theory process several factors shaping participants perceptions of and relationship with carnivores were identified.

Four primary limitations to livestock production were identified by participants in the study: drought, disease, predation and theft. Of these, predation was the only factor in the immediate environment that farmers felt they could have any control over, and hence lethal predator control persisted in the study area. The complex and sensitive history of South Africa regarding carnivore control and management (see Kerley, Wilson and Balfour, 2018) likely further shaped participants' relationship with carnivores. Deeply rooted dissatisfaction and contention between farmers and the government can subsequently result in carnivores being at the focus of farmers' frustrations. Such feelings of hostility are likely not unique to the participants of this study and have been documented previously in South Africa (e.g., Terblanche, 2020). The use of lethal control methods can be regarded as an act of frustration that occurs as a result of multiple triggers. Exploring the context surrounding the human-carnivore relationship therefore reveals why carnivore persecution is likely to occur and helps to identify areas that need addressing to achieve HCC goals.

Of note were the contrasting perceptions between stakeholder groups on carnivore population densities and trends. In this study, the majority of farmers (14/20) reported carnivore numbers to be high and increasing. In contrast, only one conservationist perceived numbers to be high, with the majority reporting populations as medium or low. Farmers gave multiple reasons as to why they perceived carnivore populations to be increasing although three main categories emerged - farming practices, environmental changes and economics. The development of technology and equipment to aid agricultural production (e.g., use of boreholes) was considered by farmers to attract carnivores and enable them to live in areas that they would not have been able to previously. Alongside this, an increase in game and hobby farmers was perceived to reduce the use of carnivore control methods since these farmers had less interest in making a living from farming. Furthermore, the removal of hunting permits for leopard between 2016 and 2018 (South Africa Government, 2018) was reported to have increased leopard numbers and removed the value of having leopard on the farm since hunting permits were regarded by some farmers as a compensation (of sorts) for losses.

The perception that carnivore populations are increasing raises questions which have implications for conservation and the achievement of HCC goals. If farmers perceive carnivore populations as high and increasing, it is logically important that they utilise HCC interventions. This aligns with the fact that most farmers (17/20) used some form of livestock protected method and were motivated to implement interventions for the sake of preventing depredation. However, the use of lethal control may potentially be justified by farmers on the basis of an increasing carnivore population and belief that their actions will not jeopardise overall population numbers. Such thinking was articulated as a disbelief that carnivores could ever be entirely eradicated since historical efforts to remove carnivores from all farming areas have thus far been unsuccessful. The emergence of such opinions revealed inter-stakeholder differences regarding the consequences of lethal control. Moreover, a minority of farmers felt that conservationists did not fully understand farmer perceptions (in regard to numbers). Differing perceptions therefore mediate how stakeholders perceive carnivore abundances with farmers and conservationists having different views on when carnivores can be considered as common or present in low numbers (Camino *et al.,* 2020; Torrents-Ticó *et al.,* 2021). In turn, this affects perceptions and use of HCC interventions. If local land users do not consider carnivore loss to be a concern, it is unlikely that measures to protect carnivores will be adopted. Exploring the context surrounding HCC scenarios prior to intervention implementation and evaluation is therefore necessary to reveal similarities and differences between stakeholders regarding drivers and barriers to HCC. Without fully understanding these, it is unlikely that the implementation of interventions will achieve HCC goals.

Participants from all stakeholder groups reported that lethal control still occurred in the study area; some farmers discussed the methods they used or carnivores they had killed previously. Whilst some participants shared this information, others may have been reluctant to share such information or feared that it may be reported to authorities despite the researcher's assurance that all information was anonymised and used for research purposes only. Previous studies have found that some farmers continue to use lethal control despite using LGDs that were perceived as successful (Horgan *et al.,* 2020). Similarly, in this study, the use of lethal control occurred despite the use and perceived success of other intervention strategies. Continuing to use lethal control methods is counterproductive to strategies designed to reduce livestock losses and increase HCC (McManus *et al.,* 2015; Thorn *et al.,* 2015; Treves, Krofel and McManus, 2016; Nattrass *et al.,* 2020). If perceived success of HCC interventions does not necessarily lead to a reduction in lethal control, there remains a need to better understand the link between reduced livestock depredation and carnivore persecution. In this study, lethal control methods were viewed as inexpensive and easy to use. Facilitating a comparison of the costs of lethal and non-lethal methods would enable farmers to make informed decisions about intervention costs with the aim of reducing the use of lethal control methods. Furthermore, specialised questioning techniques such as Randomised Response Techniques (RRTs) (Warner, 1965) could be used to investigate illegal behaviours towards carnivores and would be a useful addition to intervention evaluations to better understand behaviour changes.

The inter-stakeholder relationship

Several studies have highlighted the importance of understanding stakeholder values in HCC studies (e.g., Manfredo and Dayer, 2004; Dickman, 2010; Lute *et al.,* 2016). However, these tend to focus on the views of one specific set of stakeholders. The inclusion of different stakeholder groups exposed the complex nature of HCC scenarios which usually involve multiple people, each with different interests. The use of Q-sort in this study (chapter 5) revealed similarities in perspectives between stakeholders but also brought to light areas of potential human-human conflict. This was particularly evident in regard to expectations of interventions and the role of collaboration in achieving success. The need for collaboration between farmers and conservationists to determine success was considered important by conservationists but not placed highly in the Q-sorts completed by farmers. This follows differences between stakeholders over importance of livestock loss as a measure of success with farmers considering the measure more important than conservationists. Where farmers determine intervention success independently using their own measures, collaboration with conservationists becomes unnecessary, particularly if farmers have financially invested in the intervention. If success is determined by reduction in livestock loss as indicated by farmers and users are satisfied with interventions, the role of conservationists therefore becomes one of helping to facilitate or measure changes in behaviour and attitude to ensure HCC goals are met.

Further areas with the potential for human-human conflict emerged in chapter 3A regarding ownership and responsibility for maintaining interventions and achieving success. To avoid tension between stakeholder, roles and expectations of interventions need to be discussed prior to implementation. Levels of trust between farmers and conservationist stakeholders were diverse with a minority of farmers expressing ideas about the roles of conservationists which were based on a stereotype rather than a specific reality. In HCC scenarios, conservationists should consider how they are perceived by other stakeholders and whether preconceptions may prevent open communication regarding local beliefs and practices (Muhar *et al.,* 2018). Developing a productive relationship between stakeholder groups was thought by all stakeholder groups to take time and needs to involve clear communication in culturally appropriate terms that clarifies the expectations of all involved stakeholders.

Despite these differences, areas of consensus between stakeholders were also apparent, e.g., acknowledgement that interventions are unlikely to stop all losses. This is particularly relevant given that there was agreement that no intervention is likely to ever be completely successful, but utilising multiple strategies will contribute towards reducing livestock losses. Areas of identified consensus could be used as a starting point in discussions to show that participants have some shared perspectives and would help develop trust between stakeholders.

Perceptions of interventions and success

A change in livestock loss was considered the primary measure of intervention success by the majority of participants in this study (n=23/31). Despite this consensus, change in livestock loss was measured in a variety of ways, e.g., numerical difference between losses before and after interventions, change in number of incidents of loss or injury and change in percentage of livestock successfully raised from birth. Additionally, change in potential for loss was considered as a measure of success. Two farmers viewed the success of HCC interventions as unmeasurable. Measures of success were influenced by various factors including costs, maintenance required, past experiences, livestock purpose & number of livestock. For example, smaller herds were considered easier to protect from predation. The varied measures of success that emerged are particularly important given that perceived extent of success is likely to influence intervention implementation.

The use of self-reported livestock loss as a measure of effectiveness has been criticised for being a measure of perceived rather than functional effectiveness (van Eeden, Eklund, *et al.,* 2018; Ohrens, Santiago-Ávila and Treves, 2019; Khorozyan and Waltert, 2021). However, the findings here show that reliance of this measure occurs at the grass-roots level and is not peculiar to the research community. Given that reduction in livestock loss was used by all stakeholder groups as a measure of success, it is probably the most relevant measure to develop shared perspectives of intervention success. If livestock loss is the measure used by farmers and likely determines whether a strategy is utilised, alternative measures of success employed by researchers or intervention evaluators may be meaningless or even contradictory to farmers, ultimately reducing engagement with HCC programs.

Chapters 3A and 5 both reveal that economic factors were the most important determinant of perceived success and intervention use for farmers. Costs in regard to implementation, maintenance and labour, were of greatest concern to farmers. In contrast, conservationists considered costs as being less important in determining success than farmers did. Previous studies have found that if a significant proportion of time, labour and money has been invested in a resource that is thought to be in competition with the needs of wildlife (e.g., livestock), then an individual may be more likely to have a more negative response towards wildlife (Gadd 2005; Karlsson & Sjöstrom 2011; Humle & Hill 2016). It follows that if interventions are put in place by external parties as a result of livestock loss but are deemed to be expensive, or not feasible for many farmers, tolerance or attitude towards carnivores may be more negative. Additionally, perceptions of success were influenced by the purpose of owning livestock and whether farmers were solely dependent on livestock for their income or had diversified income streams. Resource dependence has a direct bearing on the economic and psychological costs of living with wildlife (Bhatia *et al.,* 2019). Consequently, individual circumstances need to be understood prior to intervention implementation to ensure that the strategy is financially viable and sustainable for the farmer.

Farmers tended to rely on their own knowledge or information that had been passed down from peers in regard to intervention use and perceived success. The importance of word of mouth in shaping intervention use and success has been recognised in other studies (Wilkes *et al.,* 2018; Terblanche, 2020; Lucas *et al.,* 2022) as well as here (see chapter 3A). Similarly, familiarity with an intervention is considered to play a large role in farmers' motivation to utilise specific strategies (Bogezi *et al.,* 2019). Here, past experience emerged as a determinant of intervention use with some farmers reporting that they stopped using kraals after losing livestock from within the kraal or stopped working with LGDs after witnessing undesirable behaviour. Conservationists placing LGDs also noted how some farmers were sceptical of trying new methods such as LGDs, until they had seen others using the method with success. Ensuring that interventions work according to farmer expectations should be an essential part of HCC programmes. The importance of farmer-to-farmer word of mouth in influencing intervention use should be considered to increase engagement with HCC programmes or improve dissemination of information. It is likely that establishing a working relationship with a key farmer (e.g., community leader/farmer union representative) and transmitting information via their network would be beneficial to any HCC programme.

A further factor influencing farmer intervention use was their understanding of carnivore behaviour. Participants from all stakeholder groups agreed that predators and livestock were most likely to interact at night (chapters 2 and 4). Awareness of carnivore behaviour subsequently shaped intervention use with the majority (n=13/20) of farmers reporting that kraal use was essential to protect livestock at night. Despite this, a notable number of farmers were unaware of (or did not mention) the nocturnal habits of carnivores, indicating that additional understanding of their behavioural ecology may be beneficial for depredation risk assessment. In this regard, camera trap images showing predators moving near kraals at night may help to reinforce the use of night-time kraals and therefore increase HCC through improved husbandry practises. It should be noted that one participant of the Q-method (chapter 5), who did not align to either Factor, ranked the use of camera traps highly as a means to determine intervention success. It therefore follows that camera traps could be utilised by end-users to reinforce perceptions of intervention success. As previously mentioned, key farmers (or unions/groups) would be useful targets to disseminate information regarding carnivore behaviour and the role of camera traps in assessing intervention success. Furthermore, studies have investigated the spatiotemporal overlap in activity patterns between carnivores and livestock; improved sharing of such information between stakeholder groups would provide all stakeholders with a valuable insight into the appropriateness of conservation interventions and help intervention users to determine when livestock may be most at risk and when strategies need to be utilised.

In chapter 3B the use of LGD, kraals, electric fences, herders and lethal control methods were discussed. No strategy was unanimously considered to be unsuccessful, however, all strategies had perceived issues which could prevent their use. Combining intervention strategies (e.g., a kraal and LGD together) was perceived as the most successful way of reducing depredation. The use of combination strategies gave farmers confidence that if there was a problem with one strategy, livestock were still protected by another. The varied perceptions of this study and elsewhere, highlight that no single intervention strategy is a solution for all farmers as the success of each strategy is dependent on a complex array of unique factors (Hodkinson *et al.,* 2007). Whilst it is unlikely that there is a 'one size fits all' solution to increasing HCC (see for example, Woodroffe and Frank, 2005; Dickman, 2010; IUCN, 2020; Zimmermann *et al.,* 2021), it has previously been suggested that combining the use of two or more intervention strategies will usually result in a significant reduction in livestock losses (Gehring, Vercauteren and Landry, 2010). Farmer awareness and understanding of the benefits derived from a multi-intervention approach were prominent in this study, demonstrating alignment between academia and practice, at least in this regard.

Achieving coexistence

Since the early 2000s, the concept of coexistence has become central to much biodiversity conservation discourse. Coexistence is the focus of countless academic studies of human-wildlife interactions (e.g., Madden, 2004; Carter and Linnell, 2016; Frank, Glikman and Marchini, 2019; Pooley, Bhatia and Vasava, 2021). Despite being an aim of many HCC interventions and conservation initiatives, coexistence is seldom defined and rarely studied (Glikman *et al.,* 2021; Pooley, Bhatia and Vasava, 2021). In the current study, participants generally agreed that coexistence relates to humans and wildlife being able to live together. Whilst encouraging, caveats to being able to achieve coexistence emerged. In line with economics being a primary measure of intervention success, some farmers reported that coexistence was only possible if they were still able to make a living from livestock farming. Such feelings were reiterated by farmers who indicated that coexistence was not possible and cited financial loss as a major barrier to coexistence. Across chapters (3A and 3B) the theme of coexistence by separation emerged, for example, using electric fences and kraals to separate livestock from carnivores and preferring carnivores to live in protected areas. Such desire to separate livestock and carnivores contradicts the definition of a coexistence in which humans and wildlife are able to live together, and yet was the only means by which some stakeholders considered their personal concept of coexistence to be possible. Given the varied perspectives as to what 'living together' entails, it is vital that all stakeholders involved in HCC scenarios discuss and develop a shared definition of coexistence goals and criteria for goals to be considered achieved. As such, a pre-agreed definition of coexistence can help indicate when success is reached in HCC scenarios and/or when a definition needs to be re-assessed and adapted to a newly desired human-wildlife condition (Glikman *et al.,* 2021).

Role of social science methods

Despite recognition of the need to consider the values held by different stakeholder groups involved in HWI scenarios (St John *et al.,* 2018), this study joins very limited research on the perceptions of intervention success for different stakeholder groups involved in HCC scenarios. Research on the human aspects of HCC scenarios has broadly focused on tolerance towards wildlife (Bruskotter and Wilson, 2014), drivers of tolerance, perceptions of risks and benefits (Treves and Bruskotter, 2014) and attitude toward wildlife (Kansky and Knight, 2014). Several studies have highlighted the importance of understanding stakeholder values in conflicts over wildlife management (e.g., Manfredo and Dayer, 2004; Dickman, 2010; Lute *et al.,* 2016; Dietsch, Manfredo and Teel, 2017), whilst others have tended to focus on the values or perceptions of the public or one specific set of stakeholders (e.g., St John *et al.,* 2018). Ignoring stakeholder differences in perceptions, as revealed in the current study, will hinder attempts to achieve HCC goals and may give rise to human-human conflict.

Grounded theory is an inductive, qualitative method that allows for concepts, categories and theories to emerge from the data (Glaser, 1978). The use of grounded theory is not limited to a specific discipline (el Hussein *et al.,* 2014). However, this study joins a limited number of previous studies using it in the context of HCC (Rust, 2015; Margulies and Karanth, 2018; Bogezi *et al.,* 2019). A fundamental goal of grounded theory qualitative research is to provide a rich and contextualised understanding of the human experience (el Hussein *et al.,* 2014). In this study, the use of grounded theory allowed for a unique opportunity to generate theory and discuss relationships between emergent concepts that helped to further explain people's experiences and perceptions in relation to the complex issue of HCC in a Southern African context. This was made possible by the inductive nature of grounded theory and its ability to reveal concepts and theories that are not specific to a particular participant or setting (Glaser, 2002). Given the grounded theory approach used in this study, it is not appropriate to conceptualise the findings beyond the study (Goldthorpe and Goldthorpe, 2000). Nevertheless, although the findings of this study are primarily specific to this HCC scenario in South Africa, some of the key findings, discussed in this chapter, will likely apply to a range of other HWI contexts globally. In particular, the recommendations generated and the methodology used offer important insights and approaches to HCC in Southern Africa and beyond. Grounded theory is increasingly used as a phenomenological method to describe lived experiences (Bernard and Ryan, 2010) and therefore would be a valuable addition to other studies of human-wildlife interactions to draw out novel aspects and gain an in-depth understanding of stakeholder perceptions. In addition, grounded theory revealed that a minority of bad experiences with interventions can become widely disseminated and represent a barrier to uptake within the wider community. Such findings demonstrate why it is necessary to include multiple perspectives; omission of stakeholders who are seen as having views that are too 'extreme' can have disruptive consequences and prevent the achievement of goals (e.g., Salvatori *et al.,* 2021). Consequently, neglecting to include minority views may hinder understanding as to why interventions are not used or perceived as unsuccessful.

Alongside grounded theory, the use of Q-method (chapter 5) was highly beneficial for revealing areas of overlap and divergence between participants. Areas of identified consensus, e.g., awareness that interventions are unlikely to stop all losses, can be used as neutral ground from which to develop discussions between stakeholder groups. Providing opportunities for stakeholders to meet and discuss similarities and diverging views would enable different stakeholder groups to negotiate and interact. The facilitation of such discussion does not change values or remove conflict but would allow for exposure of different perspectives, thus facilitating opportunities for compromise and solutions through discussion. Furthermore, it may help to develop trust between stakeholder groups which here emerged as being necessary to achieve intervention success, this follows other studies where trust has been fundamental in achieving goals (Young *et al.,* 2016; Waters *et al.,* 2018).

Whilst the inclusion of social science research has increased in HCC studies, many conservation researchers still fail to recognise the complexities of social science and the idea that there are different specialities within the discipline (Lischka *et al.,* 2018). As a result, there can be challenges in applying multi-disciplinary work and approaches to HCC scenarios. Pooley, Vasava and Bhatia (2021) argue that many theses and publications present qualitative data imprecisely without proper reference to specific interviewees or interview transcription. Throughout this study, interview quotes have been used to illustrate key points and give voice to the participants. Not only does this thesis highlight the role of social science in exploring HCC scenarios, but chapter 4 also demonstrates the contribution of different knowledge sources (here using interviews and camera traps) to HCC studies. Similarly, social representations research has demonstrated how scientific knowledge can be purposefully adapted and assimilated by social groups in order to authorise their positions (e.g., Hovardas and Stamou, 2006; Wagner, 2007). Thereby, the same knowledge can be used or interpreted differently by stakeholder groups, as seen here regarding camera trap and the ability to use images to fit any rhetoric regarding population status. For example, one farmer reported a camera had shown thirteen leopards coming to drink in one night thereby assuming each image showed a different individual which shaped perception of population status. The different interpretation of camera trap images that emerged in chapter 4 connects with the findings from chapters 3A and 5 that revealed that conservationists and farmers tend to define intervention success differently. Utilising information from different sources is likely to be useful in understanding perceived population size, intervention use and subsequent conservation actions. Therefore, researchers should consider knowledge generated from different sources and/or disciplines to inform HCC goals and measure intervention success. Additionally, the use of camera traps by farmers in this study could be of benefit to conservationists as a source of additional and valuable data on carnivore presence and behaviour.

6.3 Recommendations

The findings of this research study have several implications for HCC scenarios. Most notably, the study has generated recommendations for evaluating success in HCC scenarios and implications for future research. The recommendations for evaluating intervention success are as follows:

Stakeholder-derived recommendations

- Ensure clear transparency of set-up, maintenance, and long-term costs of interventions to enable users to determine whether interventions will be financially viable.
- Prior to intervention implementation, stakeholders need to develop shared criteria for determining success and agree on the units of measurement to be used for monitoring and evaluation purposes.
- Prior to intervention implementation, stakeholders need to discuss a threshold of acceptable levels of livestock and establish expectations of strategy use.
- Develop and discuss plans to enable long-term monitoring of intervention efficacy, including proactive responses to any issues identified during monitoring. Acknowledging that changes in efficacy and the context surrounding intervention use may change is important; long-term monitoring will help to determine whether modifications to the intervention are required.

- Regular contact and discussion between stakeholder groups should occur to develop greater social trust and communication between implementors and users. Stakeholders should aim to facilitate open and honest communication regarding HCC issues, intervention use and changes in perceived success.

Researcher-derived recommendations

- Prior to implementation, all stakeholders must recognise and accept that not all interventions work for all users. Moreover, it should be acknowledged that success is context-specific and willingness to utilise and/or try different interventions is highly variable and personalised.
- The overarching conservation goals of intervention use should be discussed and developed prior to implementation. Prepare to update these as necessary throughout intervention implementation.
- Establish a relationship with key farmers/gatekeepers to utilise farmer-farmer networks to transmit information regarding intervention success and ensure the intervention is approved by farmers.

The findings of this study have revealed novel insights into perceptions of HCC and measures of intervention success. However, this has also exposed several avenues for future research. The use of livestock loss to determine success may be explained by cognitive biases such as availability heuristics which suggests that because livestock loss comes to mind most easily, it must be most important when evaluating interventions. This study did not test for cognitive biases; incorporating studies of cognitive biases may therefore help to further understand the factors shaping people's perceptions of intervention success.

This study demonstrates the value of qualitative methods such as grounded theory in understanding stakeholder perceptions and providing in-depth insight into lived experiences. Rather than continue to rely on primarily quantitative approaches or measures, as is common in the scientific literature, it is recommended that that future studies exploring the human dimensions of HCC scenarios utilise more fully the suite of established psychological research methods intended to understand human behaviours and/or perspectives. Furthermore, it would be beneficial to any HCC study to utilise an interdisciplinary approach and seek methodological advice and collaborators from appropriate experts in the field. The use of interdisciplinary approaches and established social science methodologies could be used to improve understanding of illegal behaviour towards carnivores and why lethal control may continue. This is particularly important given that in this study the use of lethal control methods continued despite HCC interventions being perceived as successful. Methods such as randomised response trials (RRTs) (Warner, 1965) could be used in intervention implementation to better understand behaviour changes towards carnivores.

The study also shows it would be useful for HCC programmes to conduct camera trap studies in areas considered as livestock-carnivore interaction hotspots, e.g., livestock kraals. It was hypothesised here that sharing of camera images may help to reassure farmers that the intervention strategies and husbandry practises they are utilising are working, but must be done cautiously so as to avoid unintended or mis-interpretation of the knowledge generated by camera traps. The sharing of camera trap images would likely also improve inter-stakeholder collaboration and dialogue regarding perceived intervention success and perceptions of HCC. Adopting such an approach would help to improve dissemination of study findings outside of academia which was noted in this study as lacking. Increased collaboration between stakeholder groups, and the sharing of camera trap images, would also provide conservationists with valuable data on carnivore presence and behaviour. The Ruaha Carnivore Project (RCP) community camera trapping programme shows that camera trap studies can be used to benefit all stakeholders (RCP, 2019); similar approaches to community engagement should consequently be utilised by other programmes.

6.4 Conclusions

This thesis set out to use a multi-stakeholder socio-ecological approach to explore HCC with a focus on exploring stakeholder perceptions and measures of intervention success. The inclusion of multiple stakeholders revealed different priorities regarding intervention success and perceptions of coexistence. Differences in perspectives bought to light areas of potential human-human conflict, a key concern for many HCC scenarios. Without fully understanding these different perspectives, interventions that are not perceived as successful or appropriate may be recommended by parties external to the end-users. Understanding which strategies stakeholders perceive as successful, as well as the factors that contribute to perceived success, will facilitate a more informed decision-making process when implementing interventions.

The perceived success of different interventions was highly context specific and varied according to individual circumstances. Given the varied perceptions of different interventions, it is unlikely that any single approach aimed at increasing HCC will be universally applicable or successful. Despite this, there was general agreement that combining interventions (e.g., a kraal and LGD together) is likely to be most successful and subsequently holds the greatest potential for increasing HCC. Overall, financial considerations and cost-effectiveness emerged as the most important factors driving intervention use and perceived success. It therefore essential to have clear transparency regarding the set-up, maintenance, and long-term cots of interventions so that users can determine whether they will be financially viable.

A reduction in livestock loss was considered the primary measure of intervention success. Given that reduced livestock loss was relied on heavily by end users of interventions, this metric is also expected to influence decision making towards intervention use and behaviour towards carnivores. There was consensus among all stakeholders that it is unlikely all losses can be stopped. Such agreement can be used as a starting point to discuss acceptable levels of loss and criteria for determining success prior to implementations. The roles of all parties involved need to be clear and agreed from the onset to ensure that expectations are realistic and can be met. Conservationists favoured long-term collaborative measures to determine success; it is therefore vital that they work to establish trust with farmers and facilitate open communication to ensure perceptions of interventions are openly shared.

Overall, the findings from this study can be used by conservationists and those implementing interventions to understand which strategies may be accepted by users as well as concerns that should be addressed prior to implementation. This study resulted in the generation of a set of stakeholder-derived recommendations for determining intervention success in HCC scenarios. It is advocated that these recommendations are put into effect prior to HCC strategy implementation to ensure the needs of all stakeholders are met and HCC goals can be achieved.

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Appendices

Appendix 1: Interview consent form

Interview Consent Form

Participant ID Number:……………..

Researcher: Chloe Lucas (Nottingham Trent University, UK)
Email: chloe.lucas2018@my.ntu.ac.uk
Director of Studies: Kat Whitehouse-Tedd, katherine.whitehousetedd@ntu.ac.uk

I am a PhD student at Nottingham Trent University (NTU), UK, investigating human-carnivore existence in South Africa. I am particularly interested in learning about the strategies you use to protect livestock and your perceptions of living alongside carnivore species, and would like to speak with you to collect data relating to this. This information will form the basis of my PhD study.

In addition to the interview, I would like to request permission to set up camera traps near to your livestock and ask you to record data about interactions between livestock and carnivores. Any camera trap images which include people will be digitally modified so as to prevent the identification of the individual. I would also like to discuss whether you have any camera traps currently on your property, and whether the data from these traps could be made available to this project.

All participation in the study is voluntary. There is no time limit on the interview and it may be as long or short as you wish. Most interviews last up to 1 hour. All questions are optional, you can choose to stop and withdraw from the study at any time and without providing a reason. You have been given a unique participant number (provided at the top of the page) and if you wish to withdraw from the study please contact me and let me know this number and I will remove your data from the project database. You can withdraw from the study up until 2 months after your interview date, after this time the information that you have provided will have been fully anonymised and it will not be possible to identify your responses.

This study will adhere to Data Protection Law. NTU sponsors this project and will act as the data controller for this study. As a publically funded institution, NTU uses personal information to carry out academic research in the public interest. Therefore, if you agree to take part in this study, I will only use your information in the ways needed to conduct and analyse the research study and with your permission.

I will audio record our discussions and transcribe into text form. The audio file will be deleted at the end of the project. Any information that could identify you and your involvement in this study, i.e. any personal data that you provide such as your name and contact details, will be stored securely and confidentially in encrypted files on a password protected computer. Only I will be able to access your personal information. Data will be anonymised where possible and analysed for recurring ideas and themes, then incorporated into the overall findings and conclusions of the research. These will be reported in my thesis and other academic forums such as academic journals. Direct quotations from your interviews may be used, but not in a way that would identify you. Resultant publications will be openly accessible through NTU's Institutional Repository, IRep. All of the data required to verify my findings, including any confidential data that you give to me, will be archived and preserved for at least 10 years. Anonymised data may be shared for use in future ethically approved research. However, confidential information, or any data that might identify you, will not be released.

If you have any questions or concerns at any time during the project, please let me know (see above for contact details).

Please read the following statements:

I confirm that I am over the age of 18. Yes ☐ No ☐

I have read the above information, understand the purpose of this study and have had the opportunity to ask questions about the research. Yes ☐ No ☐

I understand that I can stop and withdraw from this study by following the process outlined above. Yes ☐ No ☐

I give permission for the researcher to use an audio recorder during interviews. Yes ☐ No ☐

I agree that anonymous quotations from the interview may be included in material published from this research. Yes ☐ No ☐

I agree to the placement of camera traps on my property at locations to be agreed with the researcher, and collection/ use of images captured on those camera to be used for the purposes of this research. Yes ☐ No ☐

I currently have camera traps on my property which are not currently part of this study (delete as appropriate). Yes ☐ No ☐

If "yes", I agree to provide the images captured on those cameras to the researcher for the purposes of this study, and I have the legal right to do so. Yes ☐ No ☐

I agree that anonymised data (including camera trap images) can be made available for use in subsequent research studies. Yes ☐ No ☐

I give permission for the anonymised data I provide to be stored in encrypted files on a password protected computer so that it may be used for future research purposes. Yes ☐ No ☐

I understand that any personal information (e-mail addresses, names etc.) I provide will be destroyed at the end of the project, or prior if so requested. Yes ☐ No ☐

Thank you for your time and cooperation with my research project.

Signed………………………………………………….. Date ……………………

Appendix 2: Key informant question guide

Key Informant Interview Question Guide

Opening Question:

What are your thoughts on the interactions that occur between yourself and other XXX [stakeholder group] with carnivores in the area/environment/property?

The subsequent conversation may be shaped using the following questions (in no particular order):

- What are some of the biggest issues/concerns for livestock farmers in the area?
- What strategies do livestock farmers in the area use to reduce (or prevent) negative interactions between livestock and wildlife?
- Are these methods as successful? Why? Why not?
- Which methods are less successful or complete failures, or not tested?
- What do you think is the best way to live alongside carnivores/ predators?
- Do you think it is possible for livestock and carnivores to live alongside each other/ coexist?

Appendix 3: Transcription protocol

Interview Transcription Protocol

At the start of the transcript write:

- Date of transcription and transcriber ID
- List Acronyms Used:

  CL= Interviewer ID
  F0XX= Participant (ID number)
  F= Other farmer talking e.g. wife/ son
  W= Worker talking

- Semantic style transcription (literal translation) - want to transcribe everything that has been said including pauses, repeats, errors, nuances. Include any details that might be useful in analysis
- When a new question is asked put the time at the start of the question in hh:mm:ss format, followed by the interviewers/speakers initials e.g. 00:01 CL
- Use a new line for when a different person starts talking
- … = short pause, (and where sentence fades out)
- (pause) = long pauses, longer than a few seconds
- Include any repetition, errs, ermms, humm
- Make note of any background noise, interruptions e.g. (phone rings), (other voices heard) etc.
- Include things that happen during the interview within the text in brackets e.g. (coughs), (laugh), (both laugh)
- = =speech is broken or interrupted midsentence
- (overlapping)= include where overlapping occurs
- Use capitals where there is a strong emphasis on a word or phrase
- Use square brackets [ ] to represent uncertainty e.g. around words that are unclear/ mumbled
- If participant mentions someone by name put XXX (transcriptions need to be anonymous)

For example:

F011: Like a strategy-

CL: (overlapping) mitigation strategy.

F011: Yes, mitigation strategy (laughs).

Appendix 4: Q-Method consent form

Q-Method Online Informed Consent Form

Researcher: Chloe Lucas (Nottingham Trent University, UK)
Email: chloe.lucas2018@my.ntu.ac.uk
Director of Studies: Dr. Samantha Bremner-Harrison, samantha.bremnerharrison@ntu.ac.uk

I am a PhD student at Nottingham Trent University (NTU), UK, investigating human-carnivore existence in South Africa. I am particularly interested in exploring how success is perceived in human-carnivore coexistence intervention scenarios. In order to learn more about this, I am conducting a survey called Q-sort to explore stakeholder perceptions of success. Q-sort is a survey technique in which you will be asked to sort statements into an order of preference on a grid (e.g., from most agree to most disagree). This information will form part of my PhD study.

In addition to the sorting activity, you will be invited to a workshop where I will be sharing recommendations developed from my study. At the workshop you will be given the opportunity to discuss these recommendations with others who were involved in the study and I would welcome your feedback.

All participation in the study is voluntary. There is no time limit on how long you should take to complete the sorting activity once you have sorted; most activities last up to 1 hour. However, in order to complete my study within the allocated timeframe, I ask that you complete the sorting activity by 31st March. It is anticipated that the workshop will last between 2- 3 hours and we expect this to take place between April and May 2021. We will contact you closer to the time to finalise the date for the workshop. You can choose to stop and withdraw from the study at any time and without providing a reason, but prior to 30th April for the sorting activity and 1st June 2021 for the workshop. After this time the information you have provided will have been fully anonymised and it will not be possible to identify your responses. You have been given a unique participant number and if you wish to withdraw from the study please contact me and let me know this number and I will remove your data from the project database.

This study adheres to Data Protection law in the UK and South Africa. NTU sponsors this project and will act as the data controller for this study. As a publically funded institution, NTU uses personal information to carry out academic research in the public interest. Therefore, if you agree to take part in this study, I will only use your information in the ways needed to conduct and analyse the research study and with your permission. For online surveys, the GDPR compliance of the software has been checked and it is recommended that you read the privacy policy prior to conducting the activity https://qmethodsoftware.com/privacy/.

I will audio record the sorting activity (if administrated in person, if conducted via the online survey link no recording will take place) and workshop, and transcribe into text form. The audio file will be deleted at the end of the project. Any information that could identify you and your involvement in this study, i.e. any personal data that you provide such as your name and contact details, will be stored securely and confidentially in encrypted files on a password protected computer. Only I will be able to access your personal information. Data will be anonymised where possible and analysed for recurring ideas and themes, then incorporated into the overall findings and conclusions of the research. These will be reported in my thesis and other academic forums such as academic journals. Direct quotations from your interviews may be used, but not in a way that would identify you. Resultant publications will be openly accessible through NTU's Institutional Repository, IRep. All of the data required to verify my findings, including any confidential data that you give to me, will be archived and preserved for at least 10 years. Anonymised data may be shared for use in future ethically approved research. However, confidential information, or any data that might identify you, will not be released.

If you have any questions or concerns at any time during the project, please let me know (see above for contact details).

Please read the following statements: By consenting to the survey you are agreeing to the following:

I confirm that I am over the age of 18.

I have read the above information, understand the purpose of this study and have had the opportunity to ask questions about the research.

I understand that I can stop and withdraw from this study by following the process outlined above.

I give permission for the researcher to use an audio recorder during the workshop.

I agree that anonymous quotations may be included in material published from this research.

I agree that anonymised data can be made available for use in subsequent research studies.

I give permission for the anonymised data I provide to be stored in encrypted files on a password protected computer so that it may be used for future research purposes.

I understand that any personal information (e-mail addresses, names etc.) I provide will be destroyed at the end of the project, or prior if so requested.

Appendix 5: Q-method factor scores and z-scores for each statement

Appendix 5: Summary of Q-method analysis of perspectives of stakeholders towards measures of intervention success. A Q-set of 36 statements was sorted by 14 participants. The factor scores represent how each statement was ranked (-5 to +5) in the factor array (composite Q sort) for each factor. The z- scores for each factor represent a weighted average which is derived from the contributing sorts. Distinguishing statements for each factor are denoted with *; these represent statements that were ranked in a significantly different way between factors.

Statement		Factor scores		Z- scores	
Statement Number	**Statement**	**1**	**2**	**1**	**2**
1	Success is less incidents of livestock being killed by predators	1*	3	0.247	1.031
2	No livestock losses is the main measurement of success	-3	3	-1.611	0.957
3	Success is measured as declining predation as indicated by farmers	1	1	0.563	0.642
4	Successful mitigation methods prevent theft as well as loss to predators	-2	1	-0.514	0.74
5	Success is measured by testing different methods and a control with no mitigation then comparing which is best	3*	0	1.377	-0.056
6	Success is measured by increasing the % of livestock young successfully raised	2	2	0.625	0.817
7	Losses before mitigation are often inflated which makes comparing before and after losses difficult	0	-1	-0.087	-0.135
8	Success needs to be measured long term	5*	4*	2.203	1.183
9	Success of a new mitigation method can take some time to see	0	0	0.127	0.067
10	Successful methods will produce immediate results	-1	-2	-0.341	-0.946
11	Having a waiting list to get a particular method is a sign it is successful	-1	-3	-0.253	-1.245
12	Successful methods remove problem predators from the area	-3	-2	-1.416	-0.948
13	Success can't be measured, not having livestock loss is success but you don't know	-2	-2	-0.454	-0.849

	what losses would be without the mitigation method				
14	Success of methods can't be measured, it's just one of those things	-4	-4	-1.784	-1.754
15	Even with mitigation strategies, achieving zero livestock losses by predators is impossible	-1	0	-0.231	0.336
16	You can manage losses with mitigation strategies but there's no guarantee they can completely stop problems	3	2	0.851	0.805
17	Cameras help show success of methods by showing passing predators haven't got to livestock	1	1	0.185	0.654
18	Success is increasing the energy needed by predators to get to livestock	0	-1	0.001	-0.439
19	Success is measured by a reduction in interactions between livestock and predators	1*	-1	0.373	-0.777
20	Success is measured by no predator tracks inside the kraal	-3	-4	-1.198	-1.271
21	Successful methods deter predators from coming near to livestock	-1	3*	-0.202	0.972
22	Success is easier to achieve with money, if you don't have money you will lose against predators	-2	2*	-0.673	0.774
23	For success, the cost of using and maintaining the mitigation method must be worth it	2*	5*	0.749	1.889
24	Successful methods save money in the long term	0*	2*	-0.056	0.805
25	Success is changing the attitude of one person towards predators	4*	0	1.532	0.16
26	Success is changing people's perceptions of predators	1	1	0.459	0.567
27	Farmers are most likely to hear of successful methods through other farmers	3	0	0.91	0.422

28	Farmers are more likely to trust the success of a mitigation method if they hear about it from other farmers	2	1	0.847	0.711
29	Success can only be determined by the farmer	-4	-2	-1.805	-0.869
30	Only scientists can determine success of mitigation methods	-5	-5	-2.11	-2.652
31	Farmers and conservationists determine success in different ways	-1	4*	-0.261	1.369
32	Non-Governmental Organisations (NGOs) inflate the success rate of interventions	-2	-3	-0.47	-1.065
33	Scientists can inflate the success rate of interventions	0	-1	0.118	-0.42
34	Farmers expect mitigation placed by conservationists to work by stopping all livestock loss to predators	2*	-3	0.75	-1.154
35	Success is not guaranteed when mitigation is put in place by conservationists	0	-1	-0.146	-0.357
36	Success is best measured by collaboration between farmers and conservationists	4*	0	1.696	0.034