Transformation from Conflict to Coexistence with Large Carnivores in Social-Ecological Landscapes

By Louise Boronyak
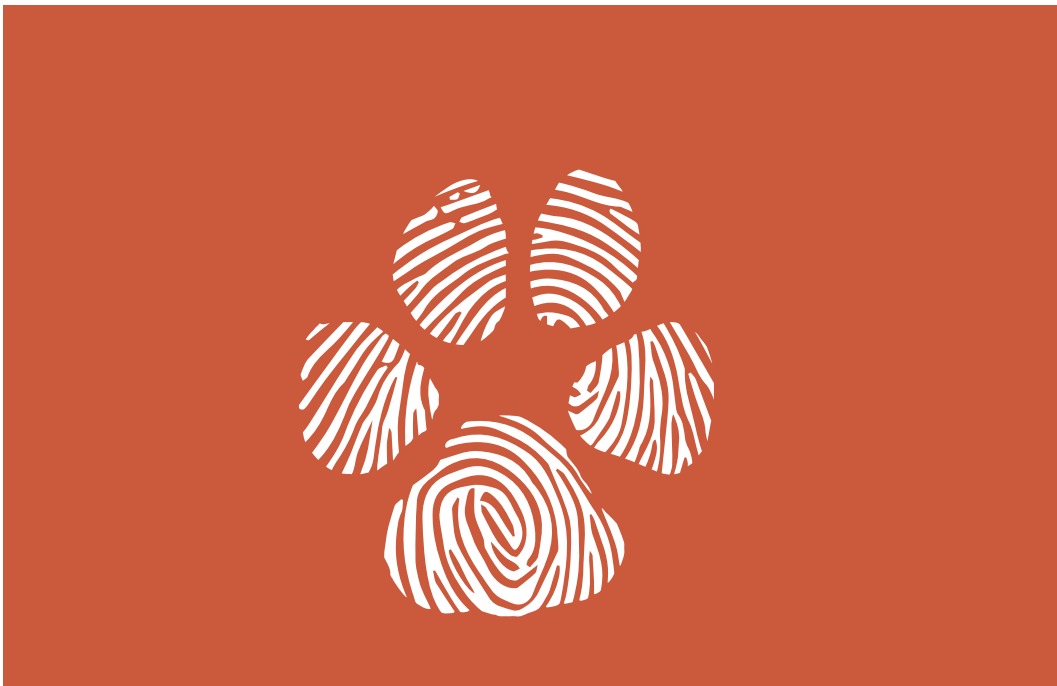
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Thesis abstract

Agriculture and biodiversity conservation are both vitally important human enterprises, yet they are often in conflict. Animal agriculture has been implicated in species loss and the degradation of ecosystems due to land clearing, overgrazing, and conflicts with wildlife. This thesis explores transformation from human-carnivore conflict towards coexistence in rangeland ecosystems where the commercial livestock production occurs. Coexistence provides a powerful way to reframe the relationship between humans and wildlife. Drawing on empirical evidence from field observations and semi-structured interviews with livestock producers, conservation researchers, grazing industry representatives and policy makers in Australia, South Africa and the United States of America I developed case studies of coexistence in each country. This thesis documents evidence-based non-lethal solutions to protect livestock and large carnivores; informs innovative policies and practices; and identifies critical pathways towards coexistence in ways that are beneficial for people, animals, and the natural world.

My thesis offers five key insights to support transformation towards coexistence. Firstly, it emphasises the urgent need to address human-carnivore conflict in extensive grazing enterprises. As conflict contributes to the global decline in large carnivores and secondary extinctions; it undermines human social cohesion; and it drives violence towards wildlife. Secondly, transformation towards human-carnivore coexistence in rangelands is achievable via pathways identified in this thesis. These pathways center on adoption of preventive non-lethal innovations supported by a new farming movement called Predator Smart Farming that balances livestock grazing and wildlife conservation values to unlock the resilience of landscapes, animals (domesticated and wild) and livelihoods. Other important pathways include research, capacity building, outreach and support for preventive non-lethal innovations; partnerships between livestock producers, experts and government and non-government organisations; institutional and cultural change; and compensation and marketing programs. Thirdly, I build on knowledge from international best practice to present pathways that facilitate adoption of Predator Smart Farming for Australian grazing enterprises. Fourthly, I explore the barriers that impede adoption of coexistence tools and practices across socio-cultural, institutional, and economic sectors. Lastly, I identify strategic leverage points to catalyse transformation towards human-carnivore coexistence by challenging the current lethal carnivore control paradigm, reforming wildlife policy and cultivating a consciousness for coexistence. Coexistence is an action, a worldview, or a destination that orients us towards living alongside wildlife in ways that are respectful, mutualistic and peaceful.

Acknowledgments

Certificate of original authorship

I, Louise Boronyak, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in Sustainable Futures at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

Signed:

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Contribution	85% Conceptualisation, literature review, data collection and analysis, writing the manuscript, revision of the manuscript, acted as the corresponding author
Co-author contribution	
First co-author	Production Note: Signature removed prior to publication. Dr. Brent Jacobs
Contribution	10% Overall research supervision, assistance for conceptual design, reviewing and editing the manuscript
Second Co-author	Production Note: Signature removed prior to publication. Dr. Arian Wallach
Contribution	5% Advice on conceptualisation, reviewing and editing the manuscript

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Contribution	80% Conceptualisation, literature review, data collection – interviews in South Africa, writing the manuscript, revision of the manuscript, acted as the corresponding author
Co-author contribution	
First co-author	Production Note: Signature removed prior to publication. Dr. Brent Jacobs
Contribution	6% Overall research supervision, assistance for conceptual design, reviewing and editing the manuscript
Second Co-author	Production Note: Signature removed prior to publication. Dr. Arian Wallach
Contribution	4% Reviewing and editing the manuscript
Third Co-author	Production Note: Signature removed prior to publication. Dr. Jeannine McManus
	1% Review of South African model
Fourth Co-author	Production Note: Signature removed prior to publication. Suzanne Asha Stone
	3% Assistance with organising US interviews, review of US model

Fifth Co-author	 Shane Stevenson 2% Assistance with organising US interviews and conceptualisation of Predator Smart Farming and review
Sixth Co-author	 Dr. Bool Smuts 3% Assistance with organising South African interviews and review
Seventh Co-author	 Hilary Zaranek 1% Contribution to thinking about financial aspects of Predator Smart Farming

Chapter 1: Introduction

1.1 The challenge of coexisting with large carnivores

Agriculture and biodiversity conservation are vitally important human enterprises that are increasingly in conflict (Bruskotter et al. 2021). Animal agriculture has been implicated in species loss and the degradation of ecosystems due to land clearing, overgrazing and conflicts with wildlife (Cocklin and Dibden 2009; Machovina et al. 2015; Johnson and Wallach 2016; Massy 2017; Pollock 2020). Coexistence between livestock grazing and carnivores is a major challenge for sustainable agriculture, animal welfare, and biodiversity species conservation.

This thesis explores a critical issue of human carnivore coexistence in rangeland ecosystems. It aims to productively channel the significant and growing societal concern for the welfare non-human animals, both wild and domestic (Bruskotter et al. 2021). Rangelands represent a variety of ecological systems including grasslands, savannah, drylands and shrublands (Davies et al. 2015; Briske 2017). Extensive grazing of livestock occurs in rangeland ecosystems, as livestock graze on vegetation found in these ecosystems.

Coexistence provides a powerful way to reframe the relationship between humans and wildlife. As a relatively new term it is both a way of interacting with others in mutually respectful and peaceful ways, but it can also be considered as a destination to strive towards. Coexistence has been defined in numerous ways:

- A balance or a negotiated compromise between humans and wildlife on how to exist together (Frank et al. 2016);
- To exist together in the same time and location with minimal risk or repercussions to each other (Bhatia et al. 2020);
- Humans and wildlife peacefully sharing landscapes (Glikman et al. 2021); and
- To learn to recognise and accommodate differences through mutual adaptations (Carter and Linnell 2016a).

Human-carnivore conflict has led to the extinction and reduction of numerous species and uncountable human deaths and economic losses (Nyhus 2016). Human-carnivore conflict arises due to the threat that carnivores pose to human interests (safety, livelihoods and resources) also from deliberate actions to conserve and restore carnivores (Treves and Karanth 2003; Dickman et al. 2011; Madden and McQuinn 2014). This creates conflict between human stakeholder groups with different viewpoints, values and knowledge of carnivores with flow on psychological, social, personal, and financial affects (Dickman et al. 2011; Madden and McQuinn 2014).

In contrast, coexistence encapsulates efforts to live alongside others with less reliance on violence to achieve human interest and goals. Coexistence with wildlife has an explicit spatial-temporal-ecological dimension, yet it also has a relational dimension as it encompasses how people can modify their behaviour and interaction with wildlife to ensure that it is based on cooperation (Marchini et al. 2019). Coexistence does not preclude risks from carnivores but rather, it necessitates human tolerance of these risks by reducing them to tolerable levels (Carter and Linnell 2016a) to achieve the "*lasting persistence of self-sustaining large carnivore populations in human-dominated landscapes*" (Chapron and López-Bao 2016 p 578).

The overarching research question addressed in this thesis is, how can human-carnivore coexistence be established in Social-Ecological systems? I use the case of extensive livestock grazing in rangelands to explore the factors that drive conflict and pathways towards coexistence. I explore case studies of extensive rangeland grazing of sheep and cattle focusing on three countries – Australia, the United States of America (US) and South Africa, which have extensive areas of rangelands used for commercial livestock production. Rangelands are important for human food security, well-being and biodiversity conservation (Davies et al. 2015). These multi-use landscapes are critical for the persistence of carnivores outside of designated protected areas (Davies et al. 2015; Hasselerharm et al. 2021). I focused my thesis on extensive grazing systems because of the scale at which carnivores are routinely killed to reduce livestock predation. This situation has entrenched human-carnivore conflict in agricultural landscapes and contributes to the global decline of carnivores (Woodroffe et al. 2005; Ripple et al. 2014). The carnivores that are the focus of my study occur in rangeland ecosystems and have been persecuted due to conflicts with grazing industry. These include dingoes (*Canis dingo*) in Australia; wolves (*Canis lupus*), coyotes (*Canis latrans*), bears (family *Ursidae)*, and pumas (*Puma concolor*) in the United States; and leopards (*Panthera pardus*), black-backed jackals (*Canis mesomelas*) and caracals (*Caracal caracal*) in South Africa.

I applied a Social-Ecological Systems lens to further knowledge about human carnivore coexistence. This is because coexistence can be viewed from a systems perspective, encompassing interactions between social and ecological components (Glikman et al. 2021). Rangelands can be considered as a linked social-ecological system as they form an interface where carnivores, prey, people and livestock co-occur (Zimmermann et al. 2010; Biggs et al. 2015; König et al. 2021). Social-Ecological Systems framing allowed me to identify the causes and drivers of carnivore intolerance and persecution to identify pathways towards more sustainable agriculture that incorporates high animal welfare and coexistence with wildlife. Advocating for more sustainable forms of agriculture requires a systems-oriented approach to understanding complex ecological, social and environmental interactions in rural areas (Pretty 1994). Extensive livestock grazing occurs in landscapes less modified and more biodiverse than in cropping systems (Scherr and McNeely 2008). This makes them ideal for the study of human-carnivore coexistence because in extensive grazing systems wild prey are often displaced by domestic livestock that are semi-free-ranging and often unprotected from carnivores (Zimmermann et al. 2010). Carnivores consume flesh as a major component of diet and by their very nature present a threat to livestock grazing. These factors make the conservation of large carnivores in human dominated landscapes challenging (Chapron et al. 2014). Accordingly, this thesis focusses on the experiences and perspectives of livestock producers, that are referred to in different countries as pastoralists, graziers, or ranchers (herein producers)

1.2 Research objectives

This thesis elucidates human-carnivore interactions in production landscapes. I have four objectives in undertaking the research:

1. Document best practices in preventive non-lethal tools and practices (herein preventive innovations) in South Africa and United States, thus revealing innovations in livestock production systems that have potential for adoption by Australian producers;
2. Improve understanding of existing barriers to the adoption of preventive innovations from personal, practical and political perspectives;
3. Engage with Australian stakeholders to document and understand factors that both enable and impede adoption of preventive innovations to reduce dingo predation; and
4. Identify the leverage points to facilitate coexistence with large carnivores across the focal countries.

Although the thesis has a strong international focus, I attempt to contextualise the preventive innovations that are most relevant to Australia. In Australia, over half of all farms raise either cattle or sheep (Frilay et al. 2015). Farms that raise beef cattle manage more than 75 per cent of the total area of agricultural land in Australia, making this the most common and widely dispersed agricultural activity in Australia (Frilay et al. 2015). Furthermore, for Australian farms, the default management practice is to kill wildlife to protect the productivity of the agricultural industry. Therefore, through changes in management practices, there is an opportunity to make an impact over a large land mass in the key drivers responsible for killing millions of wild animals each year.

1.3 Scope and contribution of this thesis

My thesis builds the evidence base to support deliberate transformations away from human-carnivore conflict towards a new positive paradigm of human-wildlife coexistence. This transformation is deliberate, because it is carried out by agents of change who have an explicit intention to achieve a goal (i.e., sustainable agriculture and wildlife conservation) and in doing so creates fundamental systemic shifts towards a more desirable future (Moore et al. 2014; O'Brien 2018). This paradigm shift alters how humans relate to wildlife in ways that accommodate the needs of humans and wildlife including carnivores, and fosters interactions that are less violent and mutually beneficial (Bekoff and Pierce 2017).

A paradigm is defined as a worldview or a general perspective (Lincoln and Guba 1985). Although a coexistence paradigm has not been realised to date, global case studies show that it is achievable and creates multiple benefits, e.g., maintaining ecosystem health and function, greater abundance and diversity of wildlife, and improved human and animal wellbeing from less stress, fear and greater cohesion (Young et al. 2015; Stone et al. 2017; Wilson et al. 2017; Boronyak et al. 2021; Schurch et al. 2021). By learning to coexist in the scenario of rangelands grazing, I hope that the lessons may be transferred to many other contexts. I use the pastoral industry as a case study to learn how to become more tolerant and compassionate towards other species that we share this planet with. This entails a paradigm shift in which the interests of wildlife are not automatically subsumed under the needs and desires of humans.

Throughout the thesis, I use the term preventive innovations to encompass various proactive tools and practices that aim to minimise or prevent livestock predation yet are non-lethal to wildlife. Similarly, Cleary et al. (2021) uses the term preventative behaviours humans can take to reduce human-wildlife conflict. Much et al. (2018) argues the importance of using non-lethal measures preventatively to take advantage of carnivore neophobia and curtail learned behaviour to seek out anthropogenic good sources that can lead to conflicts. The term aims to overcome the division that can be created between stakeholders with different values associated with use of the term non-lethal.

The adoption of preventive innovations by producers is a critical pathway towards coexistence that can create a 'win-win' situation by simultaneously mitigating livestock predation and reducing the reliance on pre-emptive and retaliatory killing of carnivores. While there are many tools and methods encapsulated within the term preventive innovations, I have classified these across three key areas: livestock husbandry (e.g., guarding and herding), enclosures (e.g., night pens, fencing), and predator deterrents (e.g., flashing lights). Each of the tools and practices work in different ways and can be adapted to the local context (livestock type, terrain, local wildlife). Furthermore, preventive innovations can be used individually (e.g., guarding dogs) or in combination (e.g., dogs by day, pens by night). This reflects contemporary thinking about fostering human tolerance by reducing the costs of living alongside large carnivores and increasing the benefits of wildlife to shift interactions from conflict to coexistence in shared landscapes (Lindsey et al. 2009; Slagle et al. 2013).

Even though some of these practices have a long history, I consider them to be innovations because they are being applied in a context in which lethal control is the norm, and because they involve the implementation of ideas, technologies or practices that result in enhanced social, ecological or economic benefits. Preventive innovations, often developed by trial and error over many years, are now also being supported by scientific studies that evaluate their effectiveness across a range of contexts (Treves 2007; McManus et al. 2015; Johnson and Wallach 2016; Treves et al. 2016; Slagle et al. 2017; Stone et al. 2017; van Eeden et al. 2018a). Some scientists have speculated that carnivores that live far from humans can be wary of certain types of man-made objects in the landscape opening opportunities to explore their value as deterrents to reduce harm to carnivores. For example, the observation that wolves can be wary of flapping material led to the development of fladry in Idaho (Stone et al. 2017). Preventive innovations provide a viable alternative to carnivore persecution and form a core of sustainable agriculture.

1.4 Research Questions

This thesis will examine the overarching research question:

RQ1: How can human-carnivore coexistence be established in extensive rangelands ecosystems?

RQ1: will be explored in research findings (chapters 4, 5, 6 and 7) through four research sub-questions (SQ):

SQ1: What is the rationale for building human-carnivore coexistence in rangeland ecosystems?

SQ2: What are the key pathways to foster human-carnivore coexistence?

SQ3: What are the major barriers that impede the adoption of preventive non-lethal innovations and how do they operate across the focal countries?

SQ4: What are the leverage points to facilitate adoption of preventive innovations by the Australian grazing industry?

1.6 Thesis structure

This study is presented as a thesis by compilation (structured as a single manuscript that comprises a combination of chapters and published/publishable works) consisting of nine Chapters:

Chapter 1 – Introduction: this chapter provides the rationale for the study; defines some important terms used in the thesis and outlines the structure of the thesis.

Chapter 2 – Literature Review: presents literature from four key areas that underpin this thesis:

1) Social-Ecological Systems that form the interface of interactions between humans, livestock and carnivores;
2) Human-carnivore interactions in Social-Ecological Systems;
3) Farmer adoption of preventive innovations; and
4) Transformation in Social-Ecological Systems.

In extensively researching and writing this thesis, I seek to support the deliberate transformation towards human-wildlife coexistence in Social-Ecological Systems. The literature review takes a deep dive into the dynamic interactions and interdependencies between humans and nature in Social-Ecological Systems. Within the spectrum of interactions, I focus on how conflict with large carnivores in rangelands has become entrenched and exacerbates the global loss of biodiversity (Ripple et al. 2014; Nyhus 2016). Populations of many species, especially large carnivores, have significantly declined as a result of such conflicts, and wide scale intervention, hence transformation, is urgently required (Zimmermann et al. 2010; Ripple et al. 2014).

Large carnivores are considered valuable focal species for conservation efforts (Terborgh and Estes 2010; Boitani and Powell 2012; Tshabalala et al. 2021). Conservation efforts have been directed to finding ways to reduce conflict and foster coexistence with large carnivores in multi-use landscapes via the use of preventive innovations (McManus et al. 2015; Stone et al. 2017; Young et al. 2019; Smith et al. 2020). However, many of these tools and practices are yet to be adopted widely by producers. I reviewed the rich body of literature on farmer adoption of preventive innovations to improve the ecological sustainability of agriculture. I sought to understand the factors that enable or constrain adoption and understand how preventive innovation can transition from niche to mainstream adoption (Geels and Schot 2007; Geels 2011). Lastly, I explored the literature on transformation in Social-Ecological Systems, specifically leverage points for transformation (Meadows 1999; O'Brien 2018), how to foster transformation holistically across three perspectives or 'spheres' the practical, political and personal (O'Brien 2018) and the phases of Social-Ecological Systems transformation (Moore et al. 2014).

Transformations generally begin with a perturbation or crisis that serves as an opportunity (Moore et al. 2014). Transformation is critical for regions where humans are degrading the capacity of the system to self-organize, maintain diversity, and provide critical ecosystem functions (Moore et al. 2014). The loss of wildlife across the globe constitutes a major social and ecological crisis (Ferrier et al. 2019). In the case of transformations for coexistence, certain stakeholder groups aim to deliberately disrupt the dominant state i.e., human-wildlife conflict that has locked Social-Ecological Systems into an unsustainable trajectory of biodiversity loss and ecosystem dysfunction. Moore et al. (2014) presented a framework that outlines three distinct phases in a transformation and subprocesses within the phases that actors can expect to face when they are deliberately attempting to stimulate or support transformation:

- Phase 1: Preparation for transformation (sub processes: sensemaking of the current system and alternative pathways, envisioning desirable futures and building momentum through creating supportive networks and an enabling environment).
- Phase 2: Navigating the transition (sub processes: selecting key pathways to invest in, learning how pathways work and adopting niche innovations); and
- Phase 3: Institutionalising the new trajectory (herein referred to as stabilising the new paradigm transition (sub processes: routinisation to embed a new trajectory and establish or strengthen new feedbacks, strengthening cross-scale relationships, stabilisation of the new transformed system.

I use this framework firstly, to demonstrate the contribution of my thesis to catalysing transformation towards human-carnivore coexistence (shown in Figure 1 in green). Secondly, to help wildlife researchers and conservationists take stock and assess progress towards transformation for coexistence, and to understand what work still needs to occur.
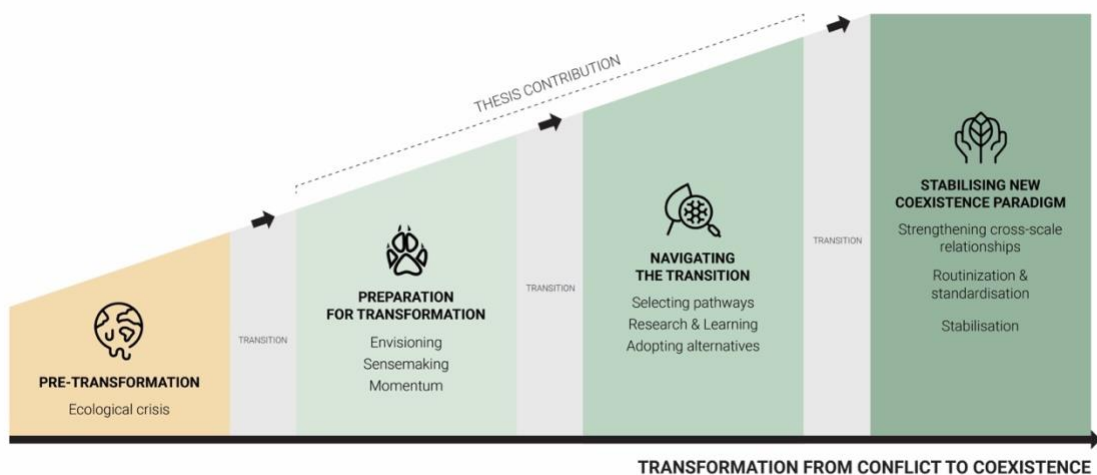
Figure 1: Graphical depiction of thesis contribution to phases of transformation within Social-Ecological Systems

Chapter 3 – Methods: presents the research questions, theoretical frameworks and how they were used, how I conducted the research methodology and my compliance with ethical research principles. Because this study is structured as a thesis by compilation, the methods Chapter is largely a compilation of the methods sections contained within Chapters 5, 6 and 7 (the thesis empirical findings), meaning there is some overlap of the material.

Chapter 4 – *Transitioning towards human–large carnivore coexistence in extensive grazing systems*, was published in the peer-reviewed journal Ambio (May 2020). It contributes to the pre-transformation phase as it synthesises the argument for the Social-Ecological Systems crisis and the importance of coexistence in that context (Moore et al. 2014). This chapter articulates four key rationales of why we must transform from a conflict paradigm to a coexistence paradigm, as:

1) Livestock production is a dominant terrestrial land use globally;
2) Large carnivores provide critical contributions to ecological health and function;
3) The persecution of large carnivores has high ethical, welfare, reputational and social costs; and
4) Lethal control of carnivores can be counterproductive to reducing predation risk.

Chapter 5 – *Pathways towards coexistence with large carnivores in production systems*, was published in the peer-reviewed journal Agriculture and Human Values (June 2021). It documents 'Business as Usual' in current grazing systems and the factors driving human-carnivore conflict. It identifies transition pathways towards coexistence with large carnivores and envisions a transformed future for rangelands grazing in the US and South Africa. The pathways operate across a variety of scales from the local-regional level to the global level and provide a bridge between the current 'conflict paradigm' in which large carnivores are heavily persecuted, towards a vision of a 'coexistence paradigm' in the year 2040. A desirable transformed future is broadly envisioned as healthy and functioning ecosystems that support biodiversity conservation, diverse livelihoods and thriving rural communities. This transformed future is more socially acceptable, ethically appropriate and supports producer livelihoods in conjunction with the conservation of carnivores. The two transformation models make a

critical contribution to the 'preparing for the transformation' phase that involves making sense of the current situation, envisioning a more desirable and inclusive future and mobilising support by identifying the most effective pathways for transformative change (Moore et al. 2014).

Chapter 6 – *Ahead of the herd… What distinguishes predator-smart producers from conventional producers of livestock?* This chapter is written in the form of a journal manuscript that explores the barriers to transformation across the three spheres (practical, political and personal) with a specific focus on barriers that create the greatest impediment to the adoption of preventive innovations (O'Brien 2018; Boronyak et al. 2020). This issue is examined from three perspectives. Firstly, identifying the major barriers that producers in US and South Africa face when considering whether to adopt preventive innovations. Barriers were classified across the three spheres to enable their clear identification, how they operate and the precise scale at which to apply interventions. Secondly, exploration of the most constraining barriers and how they act to reinforce the existing human-wildlife conflict paradigm. Thirdly, identification of the common traits exhibited by more innovative producers that set them apart from conventional producers and place them 'ahead of the herd' in terms of displaying leadership in ecologically sustainable agriculture.

Chapter 7 – *Unlocking lethal dingo management in Australia.* This chapter investigates barriers that constrain adoption of preventive non-lethal innovations in Australia. I identify the barriers and describe how they keep Australian livestock producers 'locked-in' to a conflict paradigm with dingoes. By characterising lock-in traps, I explain the ongoing reliance on lethal wildlife control practices in Australia, despite growing evidence of ineffectiveness, and the emergence of alternative non-lethal practices to reduce predation. The chapter also highlights the experiences of innovative producers who are coexisting with dingoes. Although all three countries were studied the Australian chapter has been separated out intentionally. This is because the Australian case study was always intended to be informed by the US and South African research and compared in chapter 8.

Chapter 8 – Discussion: Building on previous chapters I identify six alternative pathways and articulate a transformed future for Australian grazing. The pathways towards coexistence with dingoes were developed through reflection on empirical data collected in Australia and cross-country comparison with US and South Africa. I also discuss the similarities and differences in the barriers to coexistence across the three focal countries. I identify the overarching leverage points that alter social or ecological feedbacks to establish and strengthen the transformation towards human-carnivore coexistence. The key points in the discussion are supported by case studies from the most successful coexistence projects globally. I also discuss the limitations of this research.

Chapter 9 – Conclusions, summarises the answers to the research questions and draws conclusions from the research.

1.6 Summary

In summary, transformation from the current conflict paradigm characterised by the unsustainable persecution and intolerance towards local wildlife towards a more positive paradigm of coexistence forms the centrepiece of this thesis. My research aimed to challenge long-held preconceptions and negative biases against carnivores; document evidence-based non-lethal solutions (termed preventive innovations) to protect livestock and carnivores; inform innovative policies and practices; and identify pathways towards coexistence in ways that are beneficial for people, animals and the natural world.

This thesis is focussed on addressing the underlying causes of biodiversity loss from human intolerance, reducing direct pressures on biodiversity and safeguarding ecosystems. In the next chapter I review the literature on Social-Ecological Systems, human-carnivore interactions in Social-Ecological Systems, farmer adoption of preventive innovations and transformation in Social-Ecological Systems.

Chapter 2: Literature review

This literature review covers four key areas that underpin the multi-disciplinary approach to improving human-carnivore interactions adopted in this research:

1) Social-Ecological System that form the interface of interactions between humans, livestock and carnivores;
2) Human-carnivore interactions in Social-Ecological Systems;
3) Factors influencing adoption of preventive innovations, and
4) Transformation in Socio-Ecological Systems.

2.1 Social-Ecological Systems

This first section focusses on conceptualising interactions between humans and nature, with a focus on ecosystems, ecosystem services and social-ecological systems. Social-Ecological Systems thinking represents the outcomes of coupled interactions between human and natural systems. Humans, domesticated livestock and wild species are important parts of a Social-Ecological Systems (Biggs et al. 2015). Natural systems are a dynamic complex of living plant, animal, and microorganism communities that are interconnected with their non-living environment that function as a unit (herein ecosystems) (Millennium Ecosystem Assessment 2005; Meadows 2009). Ecosystems have both intrinsic value and provide crucial goods and services that support the survival of human and more-than-human communities. Due to the importance of ecosystems, they are a key focus in global conservation and development arenas (Reyers et al. 2013). However, the ecosystem processes that create these goods and services are not well understood and are undervalued in the global economic system and wider society (Daily 1997). Research themes over the past 40 years have focused heavily on conservation of biodiversity and landscape planning (Torres et al. 2021). The undervaluation of ecosystems is a primary driver to convert natural ecosystems to human dominated ones to yield tangible commodities to be traded, yet this degrades and undermines the health and function of ecosystems, with negative outcomes for biodiversity (Liu et al. 2022).

Biological diversity (herein biodiversity) is the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UNEP 1992). The various interactions between the biotic and abiotic components of ecosystems as well as ecological and evolutionary processes, create the stocks and flows that underpin the ecosystem services (Mace et al. 2012). Biodiversity contributes to ecosystem services in three main ways: firstly, through contributing to ecosystem function and processes in terms of regulating and supporting services; secondly, as a final consumable ecosystem service e.g. wild medicines; and thirdly, as a 'good' that has a direct value (Cardinale et al. 2012; Mace et al. 2012). Biodiversity also has spiritual and cultural value, such as the appreciation of wildlife (Millennium Ecosystem Assessment 2005; Mace et al. 2012).

Ecosystem services are the "*conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life*" (Daily 1997 p3). This concept was intended to facilitate a greater recognition of human dependence on nature and encourage people and institutions to appreciate natural systems as vital assets (Partelow and Winkler 2016). It was envisioned that this would lead to an acknowledgement of the crucial roles that natural assets play in supporting human well-being and provide a framework to enable these tangible and intangible values to be considered and incorporated to make better decisions concerning the use of land, water, wildlife and other natural resources (Daily et al. 2009). This Ecosystem services concept became mainstream with the 2005 Millennium Ecosystem Assessment that defined Ecosystem services as the goods and services humans rely on for survival, and grouped them into four broad categories: supporting, provisioning, regulating and cultural (see Figure 2).

ECOSYSTEM SERVICES

Provisioning
- FOOD
- FRESH WATER
- WOOD AND FIBER
- FUEL
- ...

Supporting
- NUTRIENT CYCLING
- SOIL FORMATION
- PRIMARY PRODUCTION
- ...

Regulating
- CLIMATE REGULATION
- FLOOD REGULATION
- DISEASE REGULATION
- WATER PURIFICATION
- ...

Cultural
- AESTHETIC
- SPIRITUAL
- EDUCATIONAL
- RECREATIONAL
- ...

Figure 2: Categories of Ecosystem Services (Source: Millennium Ecosystem Assessment 2005)

The concept of ecosystem services has been used as a tool to facilitate coproduction and value trade-offs concerning the use of natural resources with stakeholders (Mace 2014; Partelow and Winkler 2016). Some critiques have highlighted challenges associated with the use of the ecosystem services framework to understand human- environment relationships. Firstly, ecosystems are extremely complex making it inherently difficult for humans to understand the various interactions and feedbacks that occur within ecosystems, for example the interlinkages between ecosystem services and biodiversity (Nicholson et al. 2009). Secondly, there is a lack of understanding of how human actions affect ecosystems, the provision of ecosystem services, and the ways to value those services (Daily et al. 2009). Thirdly, different social groups may have different social representations of nature, meaning they value nature, and ecosystem services in vastly different ways (Rigolot 2018). Subsequently, the valuation of ecosystem services into financial and policy decisions to inform trade-offs has been a challenge that is still being solved on the scale required (Daily et al. 2009; Aryal et al. 2021). For example, it is difficult to account for intangible values such as peace and beauty of a forest or even

reconcile market-based valuation of ES with social and cultural valuation techniques (Raymond and Kenter 2016). Daily et al. (2009) offered suggestions to build the credibility and useability of ecosystem services approaches, by:

(1) combining direct biophysical measurements with economic valuation to estimate the monetary value of ecosystem services at the scale of decisions;

(2) developing non-monetary methods for valuing human health and security, and cultural services, and incorporating these in easy-to-use, easy-to- understand, but rigorous tools for valuing ecosystem services; and

(3) developing methods for identifying who benefits from ecosystem services, and where and when those who benefit live relative to the lands and waters in question.

However, more than 20 years after ecosystem services was conceptualised and as the human population has expanded ecosystem degradation has rapidly accelerated. This degradation is driving the global loss of biodiversity, climate crisis, rising poverty and declining wellbeing of human and more-than-human communities (Thomas et al. 2004; Foley et al. 2005; Millennium Ecosystem Assessment 2005; Pimm et al. 2014; Newbold et al. 2015; Ives and Fischer 2017).

2.1.1   The relationship between humans and ecological systems

A dynamic interaction exists between humans and ecosystems (Millennium Ecosystem Assessment 2005). Both ecosystem services and Social-Ecological Systems thinking recognises the deep linkages between natural and social systems in particular, human dependence on existing and intact ecosystem functioning and biodiversity (Mace et al. 2012; Partelow and Winkler 2016). Systems are comprised of various components: the elements (stocks), interconnections between the parts of the system, and purpose of the system (Meadows 2009). Humans play a key role in determining the outcome of interactions between the components of the system (Gordon 2018). Complex systems studies provide a means to gather insight into the behaviour of Social-Ecological Systems to contribute toward making better decisions that can support human–wildlife coexistence (Costanza et al. 1993; König et al. 2021).

The challenge of resolving negative human-carnivore interactions can be considered a 'wicked problem.' Wicked problems can occur at the interface of social and ecological systems and are characterised by high levels of uncertainty as to the nature and extent of the risks involved for individuals and society, ongoing change, disputed facts and values, ethical dilemmas and competing interests, and often require high-stakes decisions (Costanza et al. 1993; van Bueren et al. 2003; Head et al. 2008). A holistic and integrated approach is required to unpack the complexity of human–wildlife interactions because these relationships are interdependent and inextricably intertwined (Bhattacharyya and Slocombe 2017; König et al. 2021).

2.1.2   Human induced changes to the environment

Human influence is a growing force shaping the planet and radically affecting wildlife. Humans modify ecosystems to affect the values and benefits that they need and desire (Mace et al. 2012). For example, by fostering species that have an intrinsic socio-cultural or economic value such as livestock or removing wild species that are perceived to be a danger, threat, nuisance,

or pest. Through a comprehensive census of the distribution of biomass on Earth, (Bar-On et al. 2018) concluded that much of the planet's wildlife has been replaced by domestic livestock, with human and livestock biomass (≈0.1 Gt Carbon) outweighing all vertebrates combined, except for fish, whereas the biomass of all wild mammals is a mere (≈0.007 Gt Carbon). Collective decisions that favour livestock species at the local scale can have global repercussions for biodiversity.

The current extinction rate of species is estimated to be 1,000 times higher than the background rate of extinction (Pimm et al. 2014) resulting in the decline of wild animals by 60 per cent between 1970 and 2014 (WWF 2018). Some termed this as the 'biological annihilation' of wildlife (Carrington 2017). This is a concern because most of the benefits derived from biodiversity are dependent on large and diverse populations of species, as each species fills a biological niche in the ecosystem that collectively work together as a whole (Mace et al. 2012). Reconciling food demands and the need for other ecosystem services, such as biodiversity, is one of the greatest challenges of the twenty-first century (Dudley and Alexander 2017). Therefore, it is imperative that we find solutions that balance the needs of people and biodiversity.

2.1.3 Conserving wildlife in agricultural landscapes

Agriculture and biodiversity conservation are vitally important human enterprises that are increasingly in conflict (Bruskotter et al. 2021). Biodiversity in rangelands is decreasing, due to overgrazing from utilisation for livestock production and conversion to cropping (Alkemade et al. 2013). Land clearing and conversion is also a primary driver of biodiversity loss. For example, Biggs et al. (2008) identified that agricultural expansion and the intensification of livestock production is a major driver of biodiversity loss in southern Africa.

Australia is amongst the top 10 countries of the world for land clearing (WWF 2015). Australia is also amongst the top seven countries that contribute more than half of global biodiversity loss (Waldron et al. 2008). A recent study by Heagney et al. (2021) found that farmers in the state of New South Wales (NSW) primarily clear land in response to economic opportunities presented by favourable market signals (i.e., price rises). Livestock prices appear to have the greatest influence on land clearing rates (Heagney et al. 2021). Agricultural clearing in NSW has been responsible for ~50 % of total land clearing (excluding the effect of bushfires) over the past 25 years with profoundly negative consequences for the health and function of ecosystems and persistence of wildlife (OEH 2016).

Globally, livestock production accounts for 18.5 per cent of the total greenhouse gas emissions which exacerbates the current climate crisis from land clearing, crop production; and emissions from enteric fermentation and manure (Steinfeld et al. 2006; Machovina et al. 2015; Ferrier et al. 2019). This creates a positive feedback loop further accelerating biodiversity loss from climate change (Thomas et al. 2004; Bellard et al. 2012). Furthermore, agriculture has altered global nitrogen and phosphorus cycles and is the single largest user of freshwater in the world (Rockström et al. 2017).

According to Fischer et al. (2006) the conservation of biodiversity in agricultural landscapes is important for three key reasons:

(1) protected areas and reserve systems alone are insufficient to safeguard biodiversity;

(2) commodity production depends on ecosystem services provided by biodiversity; and

(3) biodiversity enhances the resilience of Social-Ecological Systems to recover from climatic extremes such as droughts or management mistakes.

Wildlife tolerant practices are needed outside protected areas because the conservation of wildlife inside protected areas such as national parks is insufficient to safeguard their persistence. Globally, approximately 14.7 per cent of land is designated as protected areas, however more than 30 per cent of protected lands are under intense human pressure (Jones et al. 2018). Given their expansiveness and relatively low level of modification, rangelands can contribute greatly to the broadening conservation landscapes (Hasselerharm et al. 2021). However, landscapes outside of protected areas are often hostile to the survival of many species due to human infrastructure and associated stressors, such as roads, hunting, environmental toxins and invasive species (Heller and Zavaleta 2009).

In Australia, a significant land mass (44 per cent) is allocated for grazing, whereas 89 million hectares or 11.6 per cent of the continent is designated in the national reserve system (NRS), which includes national parks, nature reserves, private conservation reserves, indigenous protected areas, and other reserve types (Watson et al. 2011; ABS 2018). A mere 7.6 million hectares of land was explicitly managed for conservation (ABS 2018). Watson et al. (2011) found that the landmass allocated to the NRS in Australia is inadequate to conserve biodiversity as these areas are not well connected, too static, not always protected from over-exploitation or external shocks and may not cover the range of rare or endangered species.

Biodiversity in production landscapes contributes to the availability of ecosystem services that underpin agricultural production such as nutrient cycling, waste decomposition, productive soils, vector control and pollination (Fischer et al. 2006; Cardinale et al. 2012). (Naidoo et al. 2008) concluded that water provision and biomass production for livestock, which benefit people close to the point of service production, were highest in areas considered as biodiversity 'hotspots'. However, the understanding of how ecosystem function contributes to agricultural production under a range of different management regimes is lacking (Daily et al. 2009). Biodiversity enhances the resilience of Social-Ecological Systems with both functional diversity and response diversity important to reduce the risk of a specific ecosystem function being entirely lost once a species is gone (Elmqvist et al. 2003). Functionally diverse ecosystems are more adaptable and can support multiple species that fulfil similar functions but may have different responses to disturbance (Heller and Zavaleta 2009). If carnivores and the ecosystem services they provide are to persist in areas where livestock production dominates, then there will be a growing need to engage with farmers as key actors in Social-Ecological Systems to find practical solutions to live alongside or coexist with carnivores in production landscapes (Gordon 2018).

Sustainable agricultural movements such as agroecology (Altieri 1989; Wezel et al. 2009; FAO 2018), Wildlife Friendly Farming (Johnson and Wallach 2016), and regenerative grazing (Massy 2017; Gibbons 2020) aim to restore and enhance resilient ecosystems capable of provisioning a full suite of ecosystem services such as biodiversity, food, fibre, water etc. on agricultural landscapes (Gibbons 2020). These approaches manage landscapes in ways that can achieve multiple outcomes for agriculture, livelihoods and biodiversity (Fischer et al. 2006; White 2008; Heller and Zavaleta 2009). Fischer et al. 2006) argue that the successful integration of conservation and production provides not only a sensible and economically profitable way forwards but also an important component in addressing the current biodiversity crisis.

Efforts to reconcile trade-offs between increasing agricultural output and conserving biodiversity have encouraged two broad approaches to agricultural production that either 'spare' land from agriculture or 'share' land with other species. In land sparing, agricultural areas are used intensively to attain higher yields from a relatively small area of land, potentially freeing up other lands for biodiversity to persist (Green et al. 2005; Fischer et al. 2008). In contrast, a land sharing strategy typically requires a larger land area to produce a comparable agricultural yield, however land is used less intensively facilitating the persistence of some biodiversity on lands used primarily for food production (Green et al. 2005; Bruskotter et al. 2021).

Animal agriculture has been implicated in species loss and degradation of ecosystems due to land clearing, overgrazing and conflicts with carnivores (Cocklin and Dibden 2009; Machovina et al. 2015; Johnson and Wallach 2016; Massy 2017; Pollock 2020). Increasing attention is being paid to the wild animals that are killed as 'collateral damage' in the raising of livestock for meat. Interest is growing in Wildlife Friendly Farming due to the recognition of its ability to achieve both sustainable food production and better conservation and welfare outcomes (Hasselerharm et al. 2021; Schurch et al. 2021). Wildlife Friendly Farming is a land sparing approach that is focussed on the conservation of wildlife in agricultural landscapes, whereby wildlife is tolerated and even encouraged to persist in production landscapes (Fischer et al. 2006; Johnson and Wallach 2016; Gordon 2018). In the Karoo region of South Africa, Schurch et al. (2021) concluded that Wildlife Friendly Farming had a positive effect on biodiversity due to the higher species richness, relative abundance and the number of sites occupied by species was higher on wildlife-friendly farms compared to a neighbouring game farm and a traditional livestock farm. In the same region, Hasselerharm et al. (2021) identified that the combination of livestock shepherding, and wildlife protection provided a promising sustainable adaptive management to improve rangeland health and adapt to a changing climate. Predator Friendly Farming is a subset of Wildlife Friendly Farming that is focussed on predators (herein carnivores). Predator Friendly Farming occurs when producers make a conscious decision to adopt a range of non-lethal methods and tools to mitigate and manage the impacts of carnivores on livestock such as guard animals or audio or visual deterrents see section 2.2.4 (Johnson and Wallach 2016). Marker et al. (2003) showed that marketing predator-friendly meat could promote cheetah conservation on Namibian farmland.

While Predator Friendly Farming is intended to improve conservation of predatory wildlife, through reduced retaliatory killing, a recent paper by Bruskotter et al. (2021) highlighted the unacknowledged trade-offs between carnivore conservation and livestock production. The authors argue that if preventive innovations are successful in reducing livestock predation,

they could potentially reduce carnivores' access to food or displace the costs of conserving large carnivores to nearby farms that do not utilise preventive techniques (Bruskotter et al. 2021). Reducing carnivores' access to food especially in cases when there is a lack of native prey can reduce their fitness, have unintended welfare implications or reduce carnivore abundance (Bruskotter et al. 2021).

The challenge of halting land degradation and loss of biodiversity has been recognised in The United Nations' Sustainable Development Goal 15, called life on land that aims to '[*p]rotect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'* (United Nations 2021 p25). Furthermore, Kunming-Montreal Global Biodiversity Framework includes four goals and 23 targets to be achieved by 2030. Target four aims to ensure urgent management actions to halt human induced extinction of known threatened species and for the recovery and conservation of species,….effectively manage human-wildlife interactions to minimize human-wildlife conflict for coexistence (UN CBD, 2022). This is the first time that a consideration of human wildlife conflict and coexistence was included in the Convention of Biological Diversity. Therefore, 196 governments have now committed to ensuring human wildlife coexistence.

2.2 Human-Carnivore Interactions

This section provides an overview of human-carnivore interactions and how these interactions influence decisions and actions that affect the conservation and wellbeing of carnivores. Livestock production has direct and indirect, deliberate or unintended effects on carnivores (Gordon 2018). Conversely, living alongside carnivores can offer many benefits but it can also impose costs upon local people, animals (both domestic and wild) and the environment they inhabit (Dickman et al. 2011; König et al. 2021). The combination of high metabolic demands of large carnivores whereby they require large prey and expansive habitats, the expanding footprint of global livestock industries and recovery of some species is expected to increase interactions between carnivores, humans and domesticated livestock (Treves and Karanth 2003; Treves 2009; Ripple et al. 2014; Bhatia et al. 2020).

Human-carnivore interactions span a continuum encapsulated by persecution and intolerance of carnivores (human-carnivore conflict) at one end, through a neutral middle ground towards more mutually beneficial interactions such as tolerance and coexistence at the other end. Table 1 compiles definitions from the literature on Human wildlife interactions and shows the span of those interactions.

Table 1: Span of Human-wildlife interactions

Interaction	Definition	Example
Persecution of wildlife	A deliberate action to reduce or eliminate an individual or population of species ((Bruskotter and Wilson 2014).	Widescale and institutionally supported use of lethal control to remove individuals or supress a population. Methods include snaring, trapping and killing, poisoning or shooting. These methods are intended to cause direct harm to target wildlife.
Intolerance of wildlife	When an animal or population is perceived as being unacceptable in some way (Bruskotter and Wilson 2014).	Widescale use barries or exclusion fencing that inhibits the movement of wildlife across the landscape, limits access to territory and resources or causes entanglement. Excluded animals are often left to disperse or die slowly of dehydration, starvation, exposure or predation.
Neutral	Interactions that are neither negative or positive.	The individual or community acknowledges the existence of the wild animal. Potential negative impacts of wildlife are not reacted to although the community may not positively engage with conservation (Bhatia et al. 2020).
Tolerance of wildlife	Tolerance can be an attitude, normative belief, or behaviour leading to the accepting of wildlife and/or wildlife behaviours that one dislikes (Brenner and Metcalf 2020). Acceptance of the real and perceived risks and costs as well as the benefits of living alongside wildlife (Bruskotter and Fulton 2012; Kansky et al. 2016).	Where an individual or community protects a wild animal even in the face of wildlife damage, owing, perhaps, to the conservation or cultural significance of the species (Bruskotter and Fulton 2012).

Coexistence with wildlife	Approaches that encompass how people relate to and live alongside wildlife, in peaceful and mutually beneficial ways (Marchini et al. 2019). With neither species is inhibiting the survival or sustained existence of the other species (Glikman et al. 2021).	Active efforts to balance the costs and the benefits associated with wildlife, reducing negative interactions between humans and wildlife, mitigating levels of conflict, and human behavioural changes that decrease pressure on wildlife populations (Glikman et al. 2021). Examples use of non-lethal preventive innovations, restoring degraded landscapes (revegetating or reforesting areas); removal/elimination of items that entangle or harm species such as fencing, netting etc. Installation of wildlife friendly fencing to enable movement, wildlife corridors and habitat creation to enable the survival of wildlife.

2.2.1   Human-Carnivore conflict

Carnivores are persecuted (killed or injured) due to conflicts with humans, often referred to as human-carnivore conflict. Human-carnivore conflict arises when carnivores negatively impact human interests or activities (Conover, 2002). For example, predation of livestock or pets, damage to property, or threats to human safety and livelihoods. Over time, humankind has become locked-in to an unsustainable 'conflict paradigm,' in which carnivores are viewed primarily as a 'cost' (financial, social or ecological) and killing them is justified to improve agricultural productivity (Bruskotter and Wilson 2014). Trapping, shooting, and poisoning are primary management tools used to 'control' large carnivores. However, lethal control has high costs to carnivores in terms of injury, death, disruptions of social groups, or loss of access to resources, and cascading ecological consequences for other species and ecosystem services (Treves and Naughton-Treves 2009; Ripple et al. 2014; Nyhus 2016). The killing of large carnivores that are widely considered to be charismatic wildlife, is a highly emotive and controversial issue (van Eeden et al. 2017). Evidence increasingly shows how terrestrial ecosystems become disrupted when carnivores, such as large canid wolves, dingoes, big cats (Panthera spp.), and bears are removed (Terborgh and Estes 2010; Estes et al. 2011; Letnic et al. 2013).

Within this conflict paradigm, the welfare and wellbeing of wildlife are impacted. Carnivores are sentient and sapient beings that are self-aware and possess rich emotional and cognitive lives (Bekoff and Pierce 2017; Hovardas 2018). Animal ethics advocates consideration of the interests of sentient animals because animals value their lives and have an interest in their own well-being and experience subjective states such as stress, fear, and joy (Hovardas 2018; Wallach et al. 2018). It imbues an obligation to give due consideration and acknowledgement of how human actions may negatively impact animal interests when making decisions (Hovardas 2018). It asserts that humans ought not to cause intentional and unnecessary harm to sentient beings (Ramp and Bekoff 2015; Wallach et al. 2018). The ethical consideration of carnivores in the arena of wildlife management is important (Hovardas 2018). Humans share

this planet with many species, and the more we learn about wildlife the more we may feel a sense of responsibility to make choices and adopt behaviours that can accommodate human and wildlife needs that is the core of coexistence (Bekoff and Pierce 2017).

The term 'wildlife control' is often used as a euphemism for the killing of wildlife (Bekoff and Pierce 2017). The lethal control of large carnivores that are widely considered to be charismatic wildlife, is a highly emotive and controversial issue (van Eeden et al. 2017). This situation creates conflicts between people that value and wish to protect carnivores and people that bear the cost of living alongside carnivores in terms of safety, livelihoods or interests (Madden and McQuinn 2014). This creates division among communities, regions and nations that undermines social cohesion and can result in violent outcomes.

2.2.2   Human dingo conflict and coexistence: An Australian case study

The dingo provides an interesting case with which to explore human-carnivore conflict and coexistence (Smith et al. 2019b). Dingoes have a flexible and generalist diet that varies spatially, temporally and with prey availability (Doherty et al. 2019). Although dingoes are blamed for livestock predation, they are known to consume a wide variety of more than 200 species such as rabbits, arthropods, birds, reptiles, possums and macropods (Allen 2012; Doherty et al. 2019). It is the issue of competition with livestock that is the key driver in human-dingo conflicts which permits and justifies the liberal use of lethal control. However, lethal control of dingoes creates a vicious cycle of conflict (Smith and Appleby 2018) that is illustrated in Figure 3 below.
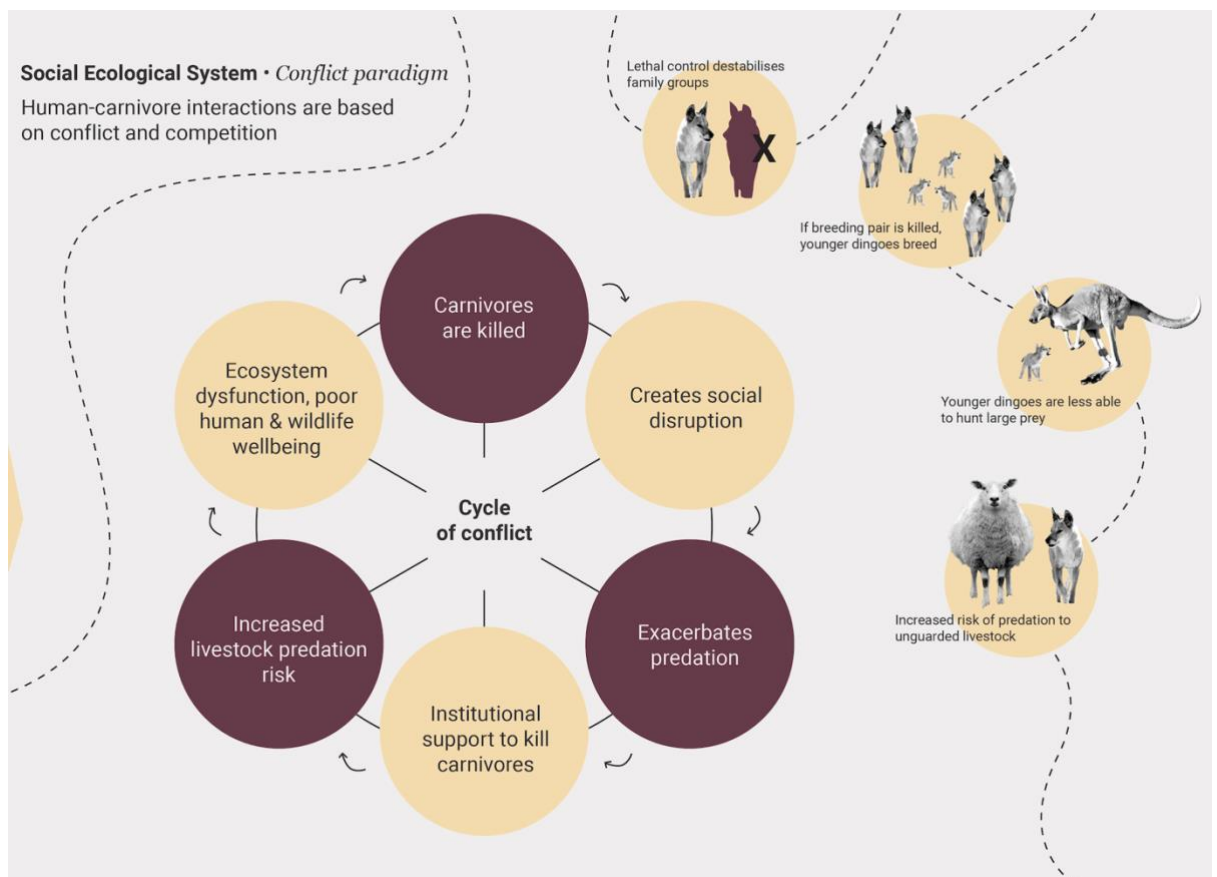
Figure 3: Cycle of conflict between humans and dingoes

Dingoes, typically live in family groups that contain one breeding pair and their young of various ages, with group size ranging from three up to 12 individuals (Smith et al. 2019). Family groups maintain a distinct territory or territories within a home range with the size of the family and territory that varies according to resources (food, water). In intact family groups only the primary male and female breed, which limits population growth. This occurs through hierarchal dominance, infanticide and territorial behaviour.

For over two centuries, dingoes have been killed via lethal methods to protect the Australian livestock industry. Lethal methods include trapping, shooting, or poisoning with meat baits containing sodium fluoroacetate (a pesticide commonly known as 1080) (Reddiex and Forsyth 2006; Pacioni et al. 2018; Philip 2019). The lethal control of dingoes can lead to social disruption by destabilising family groups, as the family may be less able to defend a territory or hunt more mobile wild prey leading to more incidences of livestock predation (Allen 2000). Furthermore, indiscriminate killing such as baiting may kill some dingoes but not all. Studies show increased livestock predation by young dingoes as they recolonise bait-induced vacant territories that can lead to higher calf loss during summer (Allen 2000; Allen 2014). Escalating predation creates a drive to kill more carnivores often supported by governing institutions leading to widescale killing thus perpetuating this cycle of conflict. This ultimately leads to ecosystem dysfunction, such as escalating loss of biodiversity as well as animal welfare implications.

Lethal control methods are supplemented by landscape-scale fences, e.g., the dingo barrier fence the longest fence in the world thar runs from Queensland to South Australia and the State Barrier Fence in southwest of Western Australia to separate agricultural areas from wildlife (Binks et al. 2015; Pacioni et al. 2018). Although fencing is considered as a non-lethal strategy, it restricts the movement of species other than dingoes and can cause entanglement and injury. Furthermore, fencing can limit the movement and migration of wildlife access to mates, food and water resulting in prolonged suffering from starvation and dehydration as well as disruption of animal social interactions and breeding opportunities with flow on effects to landscape ecology (Smith et al. 2020).

Wild canids except for foxes are generally referred to in Australian legislation and policy documents as 'wild dogs', a classification which also includes roaming domestic dogs and the hybrid descendants of dingoes and dogs (Letnic et al. 2012; Wicks et al. 2014). There is also debate over the taxonomic status and systematic nomenclature of the Australian dingo (Jackson et al. 2017; Smith et al. 2019b). While all canids share genetic similarities, modern genetic testing indicates that dingoes, wolves, and dogs are all readily distinguishable from one another (Smith et al. 2019b). However, a lack of clarity relates to the legal status of dingoes, which varies between states and with land tenure (Wicks et al. 2014). For example, in Victoria dingoes can be simultaneously declared 'protected species' and persecuted as 'wild dogs' although it is the same animal. In addition to nomenclature, the visual identification of genetically 'pure' dingoes versus hybrids versus feral dogs versus semi-owned dogs is also unclear with dingoes exhibiting a variety of colours such as tan, black and brindle (Smith et al. 2019b).

2.2.3 What is the financial cost of living alongside dingoes?

It is difficult to find an independent and transparent valuation of the losses caused by dingoes to Australian livestock industry as estimates generally include the cost of lethal control. For example, a survey conducted in 2011 and 2014 for Australian Wool Innovation attempted to value the cost of dingo predation at the landholder level by surveying 1,010 landholders (Binks et al. 2015). The survey found that farmers in wild dog affected areas spent 26 days and $7,197 a year on wild dog management (e.g., baiting, trapping, shooting, materials, contractors, fencing, compulsory pest control levies and rates) (Binks et al. 2015).

Predation loss cannot be considered in isolation to other livestock losses from poor husbandry, disease, and extreme weather (drought, fire or flooding). Wallach et al. (2017) found that of 56 cattle deaths over a 2-year period, 45 per cent related to husbandry; 18 per cent were due to natural causes and 14 per cent from dingo predation. The complex relationship between carnivore control programs and the profitability of livestock production is not well understood (Macon 2020).

It appears that most of the 'cost' of dingoes relates to the costs of lethal control rather than livestock losses to dingo predation. The reported cost of dingoes in Victoria is between $13-18 million per annum (DEPI 2013). Smith et al. (2020) found that between 2016-2017 there were 288 incidences where wild dogs or dingoes killed or maimed livestock in Victoria estimated to be worth $111,456 excluding cost of production. However, these losses represent only 0.86% of $13m reported cost of dingoes, with the remainder spent on control efforts and incentives such as bounties, employing wild dog controllers and carrying out baiting. The national expenditure on 'wild dog management' activities is reported to be more than $27 million per annum (McLeod 2016). In Western Australia under the Biosecurity and Agricultural Management Act, pastoral lease holders may be required by law to pay levies referred to as the Declared Pest Rate to fund their local Regional Biosecurity Group to lethally control declared pests in a prescribed area. In some cases, this has led to disputes because rate holders disagree with methods being used by their Regional Biosecurity Group, yet must pay for them (Pollock 2020).

A new wave of thinking is showing that dingoes can be an ally to producers especially cattle graziers (Emmott 2020; Campbell et al. 2022). Evidence indicates that dingoes could indirectly benefit some livestock producers by reducing the abundance and impact of wild herbivores contributing positively to pasture growth and soil management strategies (Wallach et al. 2010; Letnic et al. 2012; Prowse et al. 2015). This can benefit graziers through improved livestock condition, weight gain and fertility due to less competition for pasture (Prowse et al. 2015). Prowse et al. (2015) developed an economic model was developed that calculated the costs and revenues associated with trade-offs between cattle density, kangaroo abundance, calf losses and dingoes. Assuming a typical stocking density for semi-arid rangelands and an unbaited dingo population would increase pasture biomass by 53 kg ha and improve gross margins by $0.83 ha due to control of wild grazers. Furthermore, Wallach et al. (2010) found that the recovery of dingo populations may facilitate the functionality and resilience of ecosystems that underpins agricultural productivity. Ceasing dingo or wild dog control efforts and replacing with preventive non-lethal tools and practices is an economical and sensible management option for graziers.

2.2.4   Finding ways to coexist with large carnivores

Preventive non-lethal innovations include tools and practices that aim to keep livestock and wildlife safe from harm. Preventive innovations provide a compassionate way toward resolving negative interactions between humans and carnivores (Ramp and Bekoff 2015; Stone et al. 2017; Wallach et al. 2018). Decreasing negative interactions and increasing positive interactions between humans and carnivores is an important step towards building tolerance towards large carnivores in human dominated landscapes (Glikman et al. 2021). According to (Shivik et al. 2003) decreasing negative interactions with carnivores is largely a matter of altering specific behaviours of either humans or carnivores, ideally both, to facilitate co-adaptation (Carter and Linnell 2016a).

Altering human behaviour

This section summarises the various ways human can co-adapt to living alongside large carnivores, which include:

- Employing herders and range riders who stay with, guard and herd livestock as well as monitors the landscape for predators and livestock safety and health (Baker et al. 2008; Stone et al. 2017);
- Livestock management in terms of removing ill or injured livestock and eliminating food resources via removing livestock carcasses or bone yards to reduce the attractiveness of an area to predators (Shivik et al. 2003; Wilson et al. 2005). In addition, low stress handling of livestock can ensure they remain calm and have better responses to routine handling for the administration of vaccines and other medications (White 2008; Louchouarn and Treves 2021).
- Planned/holistic grazing systems that move livestock through the landscape in herds for short duration, high intensity grazing that may result in greater human presence in the landscape during herding (White 2008; McManus et al. 2018; Hasselerharm et al. 2021).
- Use of physical barriers: fencing ranging permanent electric fencing to moveable barriers. Fencing can be used specifically to herd vulnerable livestock in a pen at night (Shivik et al. 2003; Baker et al. 2008; Stone et al. 2017)
- Marketing and eco-labels: to influence the acceptable level of loss for livestock producers, using specific branding or value-added products that increase incomes for producers to offset any increased costs of implementing NLA (Bogezi et al. 2019).
- Compensation and insurance: Compensation for loss or damage to increase tolerance for carnivores and insurance designed to reduce financial impact of predation loss (Shivik et al. 2003; Macon 2020).

Altering carnivore behaviour

Both seeking and exploration are fundamental behaviours that aid the survival of carnivores through food rewards (Much et al. 2018). However, when this results in carnivores exploiting anthropogenic resources this can lead to conflict. Much et al. (2018) argue that preventing carnivores from attaining food rewards (i.e., gaining experience should suppress this innate seeking behaviours and reduce conflict. Altering the behaviour of carnivores to reduce predation risk on livestock can be achieved through the adoption of preventive innovations.

This encompasses the breadth of practices or devices that do not cause injury or death but aim to discourage, prevent, or inhibit wildlife from an area to minimise negative interactions between humans their livestock or crops (Shivik et al. 2003).

Approaches that may alter the behaviour of carnivores include:

- The use of guardian humans (herders) and/or animals (e.g., Maremma or Anatolian dogs, as well as donkeys, llamas) to deter and prevent predation (van Bommel 2013; Treves et al. 2016; van Eeden et al. 2018b).
- The use of aversive visual or audio deterrents such as lighting and fladry (Stone et al. 2017).

Carnivores alter their behaviour to co-adapt to living in a world that is dominated by humans. Kautz et al. (2021) found that the large carnivore guild in Michigan, US including wolves (*C. lupus*), American black bears (*Ursus americanus*), bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) avoided roads during the day when human activity was highest to reduce possible encounters with humans. Other activities such as hunting can also force carnivores to alter their behaviour by increasing their vigilance and spending less time foraging or engaging in other behaviours. A study of bears in Scandinavia before and after the hunting season found that bears increased nocturnal behaviour to avoid humans thus disrupting their rest time and limiting foraging opportunities before hibernation (Ordiz et al. 2012).

2.2.5   Evidence for non-lethal preventive innovations

There are increasing calls for governments worldwide to prioritise large predator conservation and their habitats, particularly by promoting the adoption and implementation of preventive innovations (Johnson and Wallach 2016). Preventive innovations decouple damage mitigation from population control and are more attractive from a conservation and animal welfare standpoint.

Consequently, the field and body of knowledge on preventive innovations is growing, and a range of methods are being tested for their efficacy (van Eeden et al. 2018a; Lennox et al. 2018) and subsequently promoted (Shivik et al. 2003; Stone et al. 2017; Young et al. 2019). Research is demonstrating that some preventive innovations may be more effective and less costly than lethal methods and are preferable from a conservation and animal protection standpoint (Treves 2007; McManus et al. 2015; Johnson and Wallach 2016a; Treves et al. 2016; Slagle et al. 2017; Stone et al. 2017; van Eeden et al. 2018a). For example, livestock guardian animals are considered more effective than lethal carnivore control (McManus et al. 2015; van Eeden et al. 2018a; Spencer et al. 2020).

Preventive innovations provide a means of keeping predators established, especially maintaining social stability while also protecting livestock from predation (Carter and Linnell 2016a). This is because some preventive innovations, such as livestock guardian animals, can have a bio-exclusive effect such that if resident predators do not kill livestock themselves, they can prevent losses by excluding other predators from the area where preventive innovations are being utilised (Shivik et al. 2003). These tools and practices are preferable to preserve trophic cascades that contribute to ecosystem health and function (Ripple et al. 2014a; Schurch et al. 2021; Tshabalala et al. 2021). Furthermore, they are more ethical because they reduce suffering and violence towards wildlife (Wallach et al. 2018) and in many cases have

proven to effectively reduce livestock predation (Rust et al. 2013; McManus et al. 2015; Stone et al. 2017; Young et al. 2019). The adaptive use of preventive innovations is outlined in Stone et al. (2017), who argues that in Idaho, North America, the adaptive use of non-lethal tools and techniques reduced losses of sheep to wolves by 90 per cent while reducing the requirement for lethal control of wolves across a large landscape.

However, preventive innovations face limitations that impact their effectiveness. Firstly, implementation of non-lethal tools and practices relies on humans with varying capacities to implement and maintain.   For example, electric fencing can be shorted circuited by vegetation so preventing this relies on humans to poison or cut grass along fence lines. Livestock guardian dogs may not bond adequately to livestock or lack training in good guardianship thus limiting the effectiveness of some tools to prevent livestock predation. Secondly, carnivores can become habituated to the non-lethal tools. If individual carnivores learn to overcome their neo-phobia or fear of predator deterrents, then stopping them from further conflict using non-lethal means becomes more difficult (Much et al. 2018).

2.1 Farmer adoption of preventive innovations

This section reviews the literature on farmer or landholder adoption to understand the factors that influence farmer decisions to adopt or reject agricultural innovation for improved conservation outcomes. This is vital to understand how the wider adoption of preventive innovations can benefit the well-being of rural communities and the persistence of wild carnivores. The application of social science in the field of conservation has grown out of recognition that conservation programs can be effective only if they incorporate an understanding of the factors that shape human behaviour (Schultz 2011).

In seeking change, environmental advocates may see limited uptake of new practices that prevent environmental harm because farming has various complex social, cultural, political, psychological and economic aspects (Pannell and Vanclay 2011). Vanclay (2004) emphasised the social basis of farmer practice adoption particularly in relation to addressing issues of agroecological sustainability and natural resource management. Environmental work often involves spreading an idea or innovation that will benefit the environment by encouraging adoption through social networks. A social network is a valuable source of knowledge and experience that farmers draw upon for reference (Pannell and Vanclay 2011).

Diffusion is considered as the spread of a phenomenon over space and through time through a social network (Rogers 1995; Wilkinson 2011). Diffusion theory is relevant in the context of changing the behaviour of a group, community or larger population (Rogers 1995; Stern 2018). Diffusion theory helps to explain this process and as well as the factors that make adoption more or less likely. However, the diffusion of innovations theory has been criticised for favouring wealthy farmers and increasing economic inequities (Stephenson 2003). Furthermore, the classical diffusion model, has been critiqued for its reliance on technological fixes and failure to consider the social context in which land users operate as well as differences across cultures (Guerin 1999).

2.1.1 Agricultural extension

Farmers, as a group in society, have been the subject of intensive study over the past 100 years, particularly in relation to the adoption of innovations such as improved soil management (Rogers 1995). Marsh and Pannell (2000 p 607) define agricultural extension as "*technology transfer, education, attitude change, human resource development, and dissemination and collection of information*. Agricultural extension is one of the policy instruments used to support agricultural development and is founded on diffusion theory (Birkhaeuser et al. 1989). It is the process of enabling change in individuals, communities or industries involved in the natural resource management or primary industries sector (Vanclay 2004). While extension has traditionally focused on educating farmers to produce better crops and more productive animals at lower cost it has been increasingly used to promote the adoption of conservation initiatives such as fencing off sensitive riparian zones for reduced erosion and improved water quality (van den Ban 1998; Marsh and Pannell 2000). Yet in Australia, publicly funded extension has declined sharply and has been replaced by industry and private consultants who utilise a user-pays approach (Guerin 1999). Lack of extension, support and financial assistance would likely hamper the adoption of preventive innovations. Kuehne et al. (2017) points out that the extensive body of knowledge of diffusion and adoption of agricultural innovations has not been simplified to make it more useable for research scientists, extension agents or environmentalists.

Pannell and Vanclay (2011) identified many conservation practices as preventive innovations for farmers because, although they may deliver significant public benefits, they may fail to provide private benefits to the farmer in the short term. Predator Smart practices fit within the category of preventive innovations as they can support biodiversity conservation (a public good) through reduced predation loss, which may in turn reduce predator persecution. Predator Smart Farming has direct benefits for livestock producers through better management of risks from predation, which is consistent with goals of maximising production and keeping their livestock safe from harm. Consequently, not all innovations that aim to conserve natural resources are likely to be readily adopted as the benefits do not always automatically translate into increasing profits (Guerin 1999).

2.1.1 Farmer adoption theory

Practice adoption by farmers is a rich and diverse research discipline and the factors that influence adoption have been well studied and are well understood (Rogers 1995; Pannell et al. 2006; Wilkinson 2011). Adoption is a complex and continuous process of learning, in which landholders are initially uncertain about a new practice, yet over time uncertainty wanes as they gain more experience and or gather more information (Pannell and Vanclay 2011; Wilkinson 2011; Kuehne et al. 2017). According to Moore et al. (2014 p5), in the social innovation, social transition, and social movement literature, adoption is "*understood to involve the widespread uptake of a novel idea into the mainstream*." Pannell and Vanclay (2011) articulated the stages landholders go through in the adoption process (see figure 4) starting with awareness, that is discovery that the innovation exists and has potential relevance to the landholder. The next step involves non-trial evaluation in which the landholder gathers information about the innovation to inform a decision to trial. If the

innovation is deemed negative then a trial would be unlikely, yet if the innovation is viewed positively then the landholder may undertake a trial and evaluate the outcomes of adopting the innovation. Then if successful, this may lead to adoption and a continuous process of review and refinement. Or, if the trial is unsuccessful or not relevant, to non-adoption (Pannell and Vanclay 2011) (shown in Figure 4).

The adoption process is iterative and never completed because the options are continuously being reviewed in light of changing circumstances and accumulation of new information (Pannell et al. 2006). Adoption can also be partial, gradual or in full as designed, and is adapted to fit the landholders' individual circumstances (Wilkinson 2011). An innovation may at some point be discontinued or dis-adopted as circumstances change or as new technologies are released and may supersede the adopted practice or technology (Guerin 1999).

The extent and speed of adoption depends upon links between landholders and others, e.g., extension officers, as well as the degree of trust and credibility (Pannell et al. 2006; Pannell and Vanclay 2011). A visual representation of the adoption process is outlined below in Figure 4. Wilkinson (2011) uses simpler terminology than Pannell such as discovery, decision and action, to describe the stages that an individual goes through when taking up a new practice, which he refers to as adoption (Wilkinson 2011).
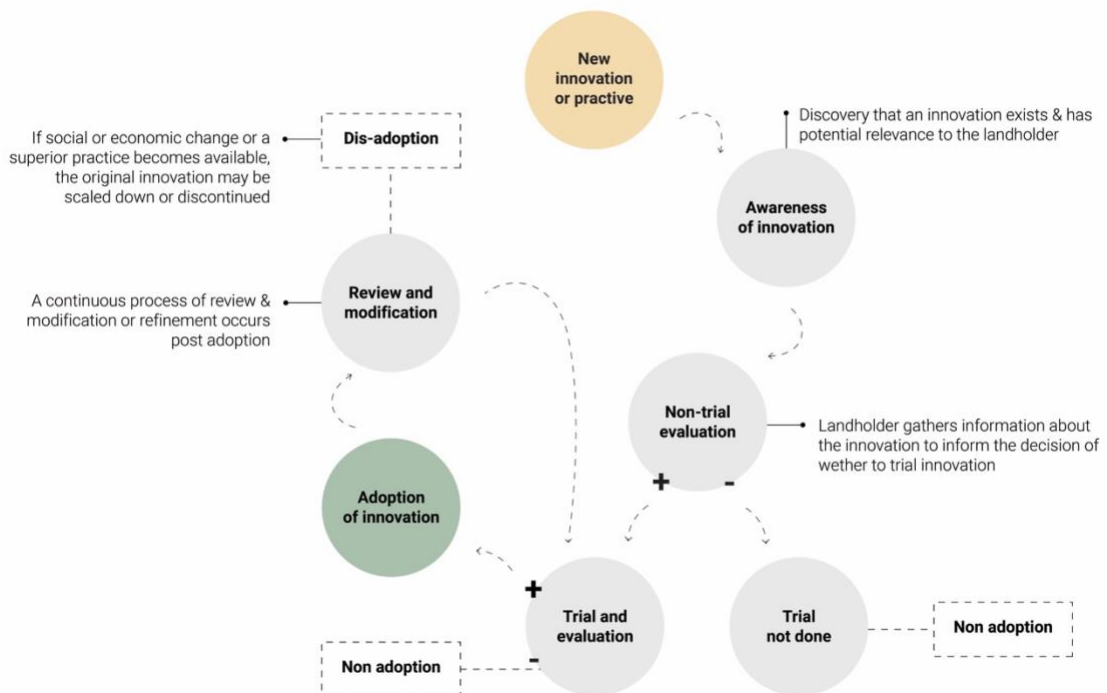
Figure 4: The stages of farmer adoption of practices or technologies (adapted from Pannell et al 2006; Wilkinson, 2011)

2.1.1 Factors that influence farmer adoption

Pannell and Vanclay (2011) suggested that practices have a higher likelihood of adoption if they have a high relative advantage (i.e., provide greater benefit than the current practice) and are readily trailable (i.e., easily tested and learned about) prior to adoption (Pannell et al. 2006; Pannell and Vanclay 2011). Trialability is affected by factors such as the costs of the trial, whether the practice can be trialled at a small scale, how observable the results are, time lags between trial and results, and the complexity of an innovation (Pannell et al. 2006; Pannell and Vanclay 2011). These two key attributes of adoption are dependent on a range of economic, social, and environmental factors.

Factors that influence technology or practice adoption can be broken down into three components:

- characteristics of the landholder such as personality, age, degree of motivation, attitude to risk, level of education, and number of dependents as well as landholders' beliefs and opinions towards the innovation (Guerin 1999; Pannell and Vanclay 2011).
- Characteristics of the agricultural enterprise including impacts on other parts of the farming system; compatibility with existing technologies and practices (Pannell et al. 2006).
- The attributes of the practice or innovation such as complexity, efficacy, perceived credibility and riskiness of the innovation (Guerin 1999; Pannell and Vanclay 2011).
- The degree of support provided for adoption influenced by the level of institutional support (Guerin 1999).

Decisions of whether to adopt an innovation or practice are also influenced by how and by whom ideas are communicated as well as the social norms and social networks of target audiences (Stern 2018). The perceived credibility of the message communicator is a powerful driver of adoption (Stern, 2018). Pannell et al. (2006) and others (e.g., Leith and Vanclay 2015) argue that agricultural extension needs to become more focused on trust, credibility, reliability, legitimacy, and the decision-making process. Opinion leaders can create new norms in a community which influence the behaviour of other land users and subsequent adoption decisions (Guerin 1999). To be able to make informed decisions, farmers may require information from different sources, yet this information may be conflicting (Van den Ban 1998). For example, there appears to be conflicting information between environmental groups and government agencies in relation to the efficacy of use of predator deterrents, such as light or noise to reduce predation risk, which would likely create confusion for producers. Uncertainty about an innovation combined with conflicting information from numerous sources (including scientists, literature, environmentalists and extension agents) can limit adoption (Guerin 1999).

Preventive innovations require a supportive environment (see Figure 5) to facilitate adoption, such as capacity enhancement approaches that build social capital (networks, relationships and trust) among opposing stakeholders through dialogue creation processes. As well as efforts to build human capital through social learning (Leys and Vanclay 2011) to develop a shared understanding of carnivore behaviour and ecology (Pretty and Ward 2001). Legislative

reform and financial support for adoption are also important. The adoption of preventive innovations is an important part of creating transformative change in Social-Ecological Systems.
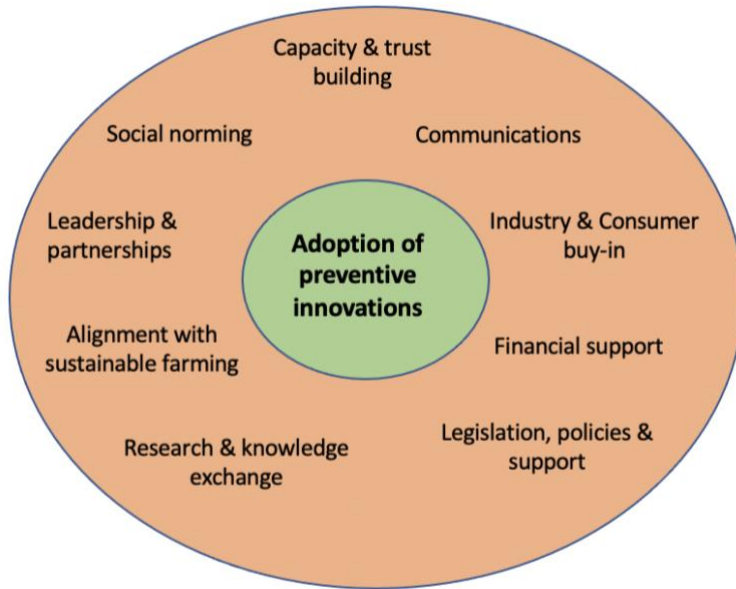
Figure 5*: Depiction of an enabling environment to mainstream adoption of preventive innovations*

2.2 Transformative change in Social-Ecological Systems

"The solutions are in our hands. Disturbing, because we must do things, or at least see things and think about things, in a different way."

Donella Meadows (2009) Thinking in Systems: A Primer

A systems-based approach can be useful to diagnose the complexity of social, political, economic, and environmental factors that impede adoption of more sustainable agricultural practices that also foster human-carnivore coexistence (Meadows 1999; Waudby et al. 2020). In 1999, Donella Meadows, a seminal systems thinker, published the Leverage Point Framework (Meadows 1999) characterised as a twelve-point hierarchy to leverage change in complex systems. It was conceptualised that a small shift in one point can catalyse large systematic changes, however leverage points vary in their effectiveness for catalysing change in systems. This framework has been used more recently, for example, Riechers et al. (2021) to identify interventions that foster human–nature connections. Karen O'Brien (2018) modified Meadows' framework to consider how to achieve the deep transformational change required to meet the global climate change target of 1.5 degrees Celsius.

2.2.1 Spheres of Transformation

O'Brien (2018) asserts that facilitating rapid social change involves deep and broad approaches that activate leverage points across three areas or 'spheres': the practical, political and personal spheres shown in Figure 6.
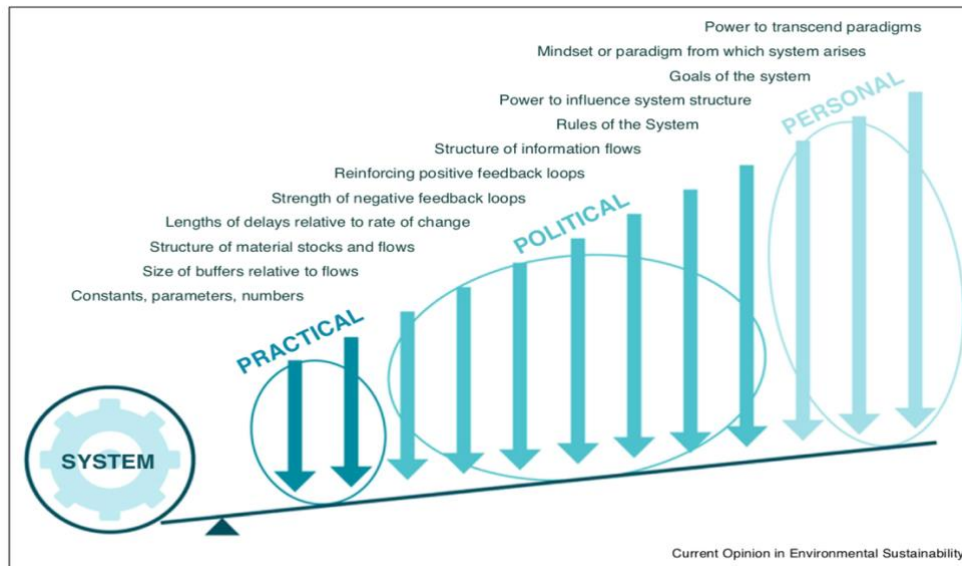
Figure 6: Leverage points for system transformation based on (Meadows 1999) and their relationship to the practical, political and personal spheres of transformation (O'Brien 2018)**.**

The practical sphere represents actions, interventions, strategies or behaviours that directly contribute to a desired outcome (O'Brien 2018). These leverage points are very tangible and elicit much attention yet are considered to be limited in their ability to affect change (Meadows 1999; O'Brien 2018). For example, in 6, two of the weakest, but commonly applied, leverage points involve making changes to parameters such as subsidies or taxes and altering the size of buffers relative to inflows and outflows in the system i.e., the amount of a natural resource. In considering the case of practical sphere innovations in extensive rangelands grazing that deter and reduce livestock predation (i.e., utilising livestock guard animals or installing electric fencing) while they may create limited change on individual farms, overall, they may be insufficient to improve the conservation of large carnivores that requires change at regional or national levels.

The political sphere comprises social structures, systems and institutions that enable or constrain practical responses (Abson et al. 2017). Leverage points in the political sphere such as the structure of information flows, rules of the system and the power to influence the structure of the system have the potential to create significant change (Meadows 1999; O'Brien 2018). This is because they are the fundamental architecture of the system, consisting of formal institutions that govern and enforce policies, laws, regulations and agreements that influence the direction of power, resources and information flows (Abson et al. 2017). The political sphere can also influence informal institutions, which include social norms, codes of conduct, or conventions that may constrain human behaviour.

The personal sphere of transformation is where both individual and shared understandings of worldviews, beliefs, values, and paradigms manifest to influence how people perceive the system and how they behave. Leverage points in the personal sphere such as the goals or intents pursued through the system, the paradigm from which system arises, and the power to transcend paradigms are thought to create the deepest levels of change (Meadows 1999; Ives et al. 2018; O'Brien 2018). The three spheres interact, for example the personal sphere is where the individual and collective ideas about what is just, preferable and sustainable are formed, which is then negotiated or contested in the political sphere and realised in the practical sphere (O'Brien 2018). Attempting to change the most powerful leverage point can also introduce major uncertainty, complexity and potentially chaos into the system (Meadows, 1999). This may be because complex systems exhibit strong and usually non-linear interactions between the elements, as well as complex feedback loops that can make it difficult to distinguish cause from effect, due to long time lags in the system stocks (Costanza et al. 1993).

Complex systems are characterised by four attributes: adaptation; self-organization; heterogeneity across scales and distributed control (Holling 2001; Pahl-Wostl 2007). Complex systems are often counterintuitive, meaning that leverage points can work in reverse causing an existing problem to systematically be made worse rather than being resolved (Meadows 2009). Consequently, global challenges such as poverty, ecosystem degradation, chronic disease and biodiversity loss are widely prevalent despite major efforts toward reducing them (Meadows 2009). Meadows refers to these as 'system traps', whereas others have referred to them as 'lock-in traps', that arise from complex social-ecological interactions (Meadows 1999; Boonstra and De Boer 2014; Haider et al. 2017). System traps such as wildlife persecution can lock a system into an unsustainable path that undermines ecological function and resilience, one that contributes to biodiversity loss and species extinction. The current scale and severity of the global loss of wildlife and biodiversity more generally warrants fundamental transformation into how human society interacts with and considers nature in decisions.

Transformation represents fundamental changes across multiple systems: social, cultural, environmental, political, economic and technological, resulting in the creation of a new system (Van Den Bergh et al. 2011; Rickards and Howden 2012; Patterson et al. 2015). Deliberate transformation involves actions by agents of change to create an enabling environment that promotes the development and expression of social consciousness (Moore et al. 2014). For example, by highlighting how the intentional human persecution of large carnivores is contributing to the global decline of biodiversity with flow on effects to local ecosystems (Estes et al. 2011; Ripple et al. 2014).

2.3 Identification of gaps in the literature

Despite the growing body of knowledge in this field of human-carnivore conflict and coexistence several knowledge gaps remain. This literature review has identified five gaps that warrant further investigation. These gaps have been used to formulate the thesis research questions that are outlined in chapter 3 (methodology). These identified knowledge gaps include:

- What are the reasons to advocate for human-carnivore coexistence?
- What are the pathways that support transformation towards coexistence and why?
- What are the factors that enable or constrain adoption of coexistence tools and practices in extensive livestock grazing systems?
- How do the factors that constraining adoption of preventive innovations operate across the three countries?
- What are the leverage points that can facilitate coexistence between livestock producers and large carnivores in Social-Ecological Systems?

Chapter 3: Methods

This chapter describes the research questions, theoretical frameworks, methodology and ethical considerations that underpin this thesis. Firstly, it presents the research questions (Section 3.1) and the theoretical frameworks (Section 3.2) used to address the research questions. Next, this chapter presents the research methodology (Section 3.3), including a case study approach and the methods of data analysis and display. Finally, I articulate my compliance with ethical research principles.

3.1 Research questions

The previous chapter identified a number of gaps in knowledge in relation to human-carnivore co-existence in production landscapes including: a need to understand the differences in approaches to human-carnivore co-existence in grazing systems in Australia, US and South Africa (three focal countries with similar systems of extensive rangelands grazing), the barriers to adoption of coexistence practices, and the leverage points that might be used to promote adoption of improved practices among livestock producers in Australia. To address these gaps, a series of research questions was formulated. The overarching question that this thesis aims to address is:

RQ1: How can human-carnivore coexistence be established in extensive rangelands ecosystems?

This overarching question will be explored in research findings (chapters 4, 5, 6 and 7) through four sub-research questions (SQ):

SQ1: What is the rationale for building human-carnivore coexistence in rangeland ecosystems?

SQ2: What are the key pathways to foster human-carnivore coexistence?

SQ3: What are the major barriers that impede the adoption of preventive innovations and how do they operate across the focal countries?

SQ4: What are the leverage points to facilitate adoption of preventive innovations by the Australian grazing industry?

3.2 Theoretical Frameworks

In this section I provide detailed information about the theoretical frameworks used to inform the data collection methods, guide the analysis and ultimately offer insights in relation to the research questions.

My thesis is multidisciplinary spanning ecology, biodiversity conservation, social sciences and innovation, consequently my thinking has been influenced by a number of theoretical frameworks, which I introduce now and describe in more detail below. I explore coexistence between humans, livestock and large carnivores in extensive (managed) grazing systems, the overarching theoretical framework used was Social-Ecological System theory. To consider how to catalyse transformation in Social-Ecological Systems I drew upon the O'Brien (2018) three spheres of transformation framework based on Meadows (1999) Leverage Points Framework.

Other frameworks addressed specific questions in different phases of the research. For example, in chapter 5 I used the Sellberg et al. (2017) framework that combines theories of social-ecological resilience with socio-technical transformation theory and builds collective action to address global sustainability challenges. To understand barriers to the adoption of preventive innovations for chapters 6 and 7 I used the Multi-Layer Perspective (MLP) of socio-technical transitions (Geels and Schot 2007), as a heuristic device, and the characteristics of lock-in traps (Haider et al. 2017). To frame the thesis discussion in chapter 8 in light of progress towards human-carnivore coexistence I drew on a framework for analysing the phases of a social-ecological system transformation process (Moore et al. 2014). In the following sections I briefly describe these frameworks and their application in this thesis.

3.2.1   Social-Ecological Systems

Social-Ecological Systems is a widely used concept in the study of the interface between social and ecological systems that provided a useful structure and guide for the data collection and analyses (Herrero-Jáuregui et al. 2018). Social-Ecological Systems are dynamic and complex systems of people interacting with natural systems (Holling 2001; Stern 2018). They share the essential features of complex adaptive systems: nonlinear feedback mechanisms, strategic interactions, individual and spatial heterogeneity, and varying time scales. The most widely studied elements of Social-Ecological Systems include the analysis of resilience, ecosystem services, sustainability, governance and adaptive management (Herrero-Jáuregui et al. 2018).

A concept that has come to be closely aligned with Social-Ecological Systems behaviour is that of system transformation. Major advances in sustainability science have been possible through employing systems thinking (Fischer et al. 2015), and how as a society we can manage change, govern and create more desirable systems to foster coexistence (Biggs et al. 2015; Stern 2018). According to (Costanza et al. 1993 p 546) and co-authors, these "*insights will be needed to change the behaviour of the human population toward a sustainable pattern, one that works in synergy with the life supporting ecosystems on which it depends.*" Studying complex systems is vital to create new knowledge and better understand the social and ecological challenges we face and how these challenges can be addressed (Meadows 2009; Biggs et al. 2015).

The concept of Social-Ecological Systems as applied in this study, not as an analytical tool, as in Ostrom (2009) and McGinnis and Ostrom (2014) but rather as a frame to aid understanding and description of the interactions among system components and for diagnosing barriers to sustainability (Partelow 2018). Specifically, a Social-Ecological Systems framing allowed me to identify the causes and drivers of carnivore persecution and intolerance as well as identify pathways towards more sustainable agriculture that incorporates high animal welfare and coexistence with wildlife.

3.2.2 Leverage points for system transformation

Johnson and Wallach (2016) argue that transitioning towards coexistence with large predators requires major policy, technical, economic, legal, and cultural change. Yet, theories of transformation in Social-Ecological Systems are evolving and its identification in practice remains somewhat contested (Pelling 2010; O'Brien 2012; Feola 2015). However, in this thesis I define transformation as a deliberate attempt to promote a major, fundamental change in Social-Ecological Systems (Feola 2015).

In considering how to facilitate a deliberate transformation towards human-carnivore coexistence I drew upon (Meadows 1999) Leverage Points Framework that identified twelve important leverage points for intervening in complex systems. Meadow's framework is flexible and can be used as an analytical tool, a metaphor and a methodological boundary object (Riechers et al. 2021). A boundary object is an artifact, document or even an idea that enables different groups to work together build a shared understanding (Star 2010). Leverage points can be shallow or deep according to the type of influence they have on a system (Meadows 1999; Ives et al. 2018). I used Meadow's framework to identify key pathways for facilitating transitions towards more ecologically centred forms of extensive grazing that encourage human-carnivore coexistence as part of sustainable agriculture. Specifically, this framework helped me uncover and characterise intervention points to enable transformation towards forms of agriculture that better sustain human and wildlife existence.

O'Brien (2018) expanded Meadows' framework by grouping the twelve leverage points across three spheres: practical, political and personal. The notion of 'spheres' is used by O'Brien (2018) to reflect areas or domains that are an intrinsic part of a larger whole. Abson et al. (2017) argue that the leverage points framework provides a promising approach for conceptualising transformation in Social-Ecological Systems because it enables us to see holistically the different elements and interrelationships of a system, yet also see the discrete elements so that they can be addressed separately.

The practical sphere represents behaviours, management practices and technical solutions that contribute towards desired outcomes (O'Brien and Sygna 2013; Gosnell et al. 2019). It is often considered the "*outcome sphere, where the numbers, parameters, and indicators are most often measured (e.g., the Human Development Index, the Red List of Endangered Species, ecological footprints etc.)*" (O'Brien and Sygna 2013 p5). The political sphere creates the conditions that either enable or disable transformations in the practical sphere (O'Brien and Sygna 2013).

The political sphere includes social and ecological systems and structures, institutions (laws, regulations, policies), and culture (social norms, codes of conduct, traditions) (Abson et al. 2017). In combination, these conditions influence the behaviour of system actors. Within the political sphere, shared interests and understandings exist. However, it is also the space where disagreement and dissent are expressed, which can produce tensions and conflicts but also the formation of new alliances and partnerships (Meadows 1999; Abson et al. 2017). Given the political sphere also involves the management of natural systems, such as ecosystems, it is an important sphere to focus attention when considering human-carnivore interactions.

The personal sphere includes aspects such as individual and collective world views, beliefs, identities and priorities. World views are defined as a deeply held set of personal beliefs that shape how we perceive the world and guide action (Guba 1990; Beddoe et al. 2009). Leverage points within the personal sphere represent "*both individual and shared understandings and assumptions about the world, which influence perceptions, interpretations and constructions of reality*" (O'Brien 2018 p156). Collective worldviews shape the emergent direction to which the system is orientated, thereby constituting the deepest leverage point (Meadows 1999; Ives et al. 2020). However, the personal sphere is insufficient on its own to generate fundamental systemic change (O'Brien 2018; Ives et al. 2020).

This framework is useful for conceptualising social transformations, and as such forms the core framework of my thesis to address the research questions. For example, the framework proved useful to classify the barriers to the adoption of preventive innovations and pinpoint which of the three spheres of influence posed the greatest impediment to, or offered the opportunities for, transformation in Social-Ecological Systems.

3.2.3   Phases and subprocesses in Social-Ecological System transformation

This thesis generates momentum for a significant paradigm shift that transforms how humans relate to and accommodate the needs of wildlife. I utilised Moore et al. (2014) Framework for analysing the multiple subprocesses in each phase of a social-ecological system transformation process to understand the stages of transformation towards coexistence (2014). This framework combines perspectives from three branches of literature i.e., social movements, social innovation and transition management to build a holistic consideration of social transformation processes that will lead to improved social and ecological outcomes (Moore et al. 2014). The Moore et al. (2014) framework identifies three phases and subprocesses faced by actors when attempting to stimulate transformation in Social-Ecological Systems:

Phase 1: Preparing for a transformation

- Sensemaking: analysis of the structures that are contributing to a crisis or challenge, its current trajectory and alternative solutions,
- Envisioning: generating new innovations and visions for the future,
- Gathering momentum: self-organisation around new ideas, building networks of support and experimentation in protected 'niches' to resolve the challenge.

Phase 2: Navigating the transition

- Selecting: choosing the most optimal innovation or change process to invest social, intellectual, and financial capital towards,
- Learning: evaluating the results of earlier experiments and developing shared understandings or new forms of knowledge,
- Adoption: widespread uptake or replication of innovative niche that was successful in experimental stage.

Phase 3: Stabilising the new paradigm

- Routinisation: managing dynamic stability to embed new trajectory and establish or strengthen new feedbacks,
- Strengthening: building cross-scale relationships to scaling up the change to make it durable,
- Stabilisation: institutionalisation of the new transformed system.

As Moore et al. (2014) argue, understanding transformation in Social-Ecological Systems requires an analysis of ecological aspects and social systems. As such, I investigated, through a review of published literature, the interactions between species (including humans) and ecosystem services, the ecological aspects such as ecosystem processes and functions (especially trophic cascades). In addition, the three country case studies explore the phases of transformation by looking at changes to social systems including norms, values, and beliefs; laws, procedures, and customs; power and decision-making (Moore et al. 2014). As a result, the deliberate transformational management of grazed rangeland ecosystems along the pathways described in Chapters five and eight could result in human-carnivore coexistence.

3.2.4 Multi-Layer Perspective of Socio Technical Transitions

Socio-technical transition theory describes niche innovations and their interactions with existing social-technical regimes (Geels and Schot 2007). This framework illuminates how innovations transition from being niche to become adopted more widely or mainstreamed (Geels and Schot 2007).

I document the existence of 'niches' of innovation and experimentation among innovative livestock producers, supported and encouraged by animal protection and environmental NGOs, and more recently government agencies. Preventive innovations can be considered as 'innovative niches' to foster coexistence with wildlife, specifically large carnivores. I used Multi-Layer Perspective of Socio Technical Transitions (Geels and Schot 2007) in Chapter 6 as a guide to identify barriers to preventive innovations in extensive grazing operations in South Africa and the US. This framework yielded insight into how niche innovations struggle to become established in the existing agri-industrial regime, and therefore helped to understand how these barriers impede adoption of preventive innovations and identify pathways to a more desirable system (e.g., Jacobs et al. 2017).

3.3 Research Methodology

In this thesis, I adopted a social constructivist worldview. In this thesis, I adopted a social constructivist worldview supplemented with analyses of the influence of macro-level factors (politics, legislation, and consumer advocacy) on the micro-level views of stakeholders (producers, researchers etc). A social construction of reality is one in which, according to Creswell (2007), the researcher seeks understanding of the world in which they live and work.

Social constructivism has been criticised on several grounds. Methodologically, which is most pertinent to this study, the need to supplement social constructivist micro-level analyses with analyses at macro-level or that place findings in the context of non-social factors have been suggested as necessary (Winner 1991). Accordingly, my thesis does not rely solely on social constructivist micro analysis of stakeholder views. Findings are triangulated through other frameworks (e.g., Meadows leverage points, and social-ecological lock-in from Resilience Thinking) that accommodate the explanatory power of macro-level factors (such as politics, legislation, and consumer advocacy).

Investigating the phenomena of human-carnivore coexistence in rangeland grazing is complex and requires deep inquiry. Qualitative methodologies enable such deep inquiry, and hence were selected to offer insight into the research questions. Qualitative inquiry, as a mode of human and social science exploration (Creswell 2007), yields detail and depth to create understanding of phenomena and lived experiences (Bowen 2010). Qualitative researchers study phenomena in their natural settings, which facilitates sense making and interpretation of the meanings that people ascribe to them (Creswell 2007). Moreover in-depth, and illustrative information aids understanding of the complexity and multiple dimensions of the problem under analysis (Almeida et al. 2017).

Quantitative research deals in numbers, logic, and an objective stance to explain phenomena (Goertzen 2017). For example, my thesis could have included quantifiable data such as the numbers of livestock lost to predators or costs of non-lethal tools. But, because of my interest in the paradigmatic leverage points of change, I focused my inquiry on aspects of human behaviour (Almeida et al. 2017). I considered a qualitative methodology most appropriate for the exploration of human-wildlife coexistence, as it is a relatively new field (at least to Western science) and is multi-faceted requiring in-depth analysis. In this thesis, the use of a qualitative research methodology enabled understanding of the range of perspectives from landholders, wildlife conservationists and government to identify and construct a positive paradigm which better balances agriculture and wildlife conservation.

I recognise that qualitative research is largely open to interpretation by the researcher, which raises the question of how can it be trusted? (Pretty 1994). This question of trustworthiness is a key critique of qualitative research especially in terms of data reliability and validity (Shenton 2004). The smaller sample sizes common to qualitative research make it more difficult to establish the validity and generalisability of results (Crescentini and Mainardi 2009). I sought to overcome this limitation by following the criteria for establishing trustworthiness developed by Pretty (1994) (see Table 2), specifically seeking multiple stakeholder perspectives and ensuring deep engagement with different actors and groups. Triangulation of data sources as means of corroboration allows the researcher to be more confident of the study conclusions (Bowen 2010). With regard to triangulation, wherever possible I used multiple lines of evidence, drawing data from a range of sources and methods – in particular, interviews, observation on farms, and document reviews (reports, newsletters and published literature). I also verified draft versions of my findings with interview participants, especially where they were directly quoted. By following a discrete set of methods, qualitative research can produce verifiable explanations of the social world (Bennett and Elman 2006).

Table 2: Components of inquiry process enhancing trustworthiness (source: Pretty (1994)

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Components of Inquiry Process Enhancing Trustworthiness

1. Prolonged and/or intense engagement of the various actors;
2. Persistent and parallel observation;
3. Triangulation of sources, methods and investigators;
4. Analysis and expression of difference;
5. Negative case analysis;
6. Peer checking;
7. Participant checking;
8. Reports with working hypothesis, contextual descriptions and visualizations;
9. Parallel investigation and team communications;
10. Reflexive journals;
11. Inquiry audit;
12. **Impact on stakeholders' capacity to know and act.**

</div>

My thesis fits into the framework of 'naturalistic' ontology. Creswell (2007) elaborates on the description of naturalist ontology as a qualitative approach with data being collected in the setting most appropriate to the people and places being studied (to keep realities in their contexts), data analysis that is inductive to establish themes and patterns and presentation of the data (Creswell 2007). Furthermore, Creswell (2007) argues that presentation of the data clearly articulates voices of participants, the reflexivity of the researcher, as well as a detailed description and interpretation of the problem, and extends the literature or signals a call for action.

3.3.1   Country case studies

The research design consisted of a series of case studies in three countries to explore human-carnivore interactions in commercial extensive grazing systems. According to Sturman (1997 p61) "*a case study is a general term for the exploration of an individual, group or phenomenon.*" A qualitative case study approach enables the exploration of a phenomenon within its context using various sources of data (Baxter and Jack 2015). Case studies provide a method to investigate complex situations with multiple variables under analysis and are useful for advancing a field's knowledge base (Almeida et al. 2017). I conducted the research for this thesis in South African, western United States and Australian rangelands, where each country formed a discrete case study that allowed a comparison of similarities and differences. These countries were selected for their vast areas allocated for extensive livestock grazing (Havstad et al. 2007; Seyfang and Smith 2007; Palmer and Bennett 2013) and a history of negative human-carnivore interactions or conflicts. Given this thesis is focussed on the real-world phenomena of humans living alongside large carnivores and wildlife more generally in mutually beneficial ways, case studies provided a nuanced view of reality from the perspective of stakeholders in Social-Ecological Systems.

The multi-country case studies provide a rich picture of potential transformations in human-carnivore coexistence in rangeland grazing. Overall, the case studies yielded information about the dynamic interactions between producers, livestock and large carnivores. According to Almeida et al. (2017 p 377) a limitation of case studies lies in the difficulty "*to establish a cause-effect connection to reach conclusions and it can be hard to generalize, particularly when a small number or case studies are considered*." As mentioned in relation to the limitations of qualitative research, I address this by engaging a wide variety of stakeholder views and triangulating data sources. The data for the case studies were developed from key informant interviews, field observations, workshops and a review of key policy documents. The case studies were linked to investigation of the four research sub questions, detailed in Section 3.1.

3.3.2   Data collection process

This section summarises the data collection process, location and method to develop the case studies. The data for the case studies were collected consecutively across three countries as follows (methods sections in Chapters 5, 6 and 7 provide further details):

1. Southern Africa, January 2018, data collected from a workshop in Namibia followed by stakeholder interviews and field observations in South Africa.

2. Western US, data from interviews and field observations were gathered during three trips in June 2018, February and October 2019, and during a coexistence summit in Montana in October 2019, in which I was a participant.

3. In Australia, interview data were collected between March 2020 to February 2021. All but one of the interviews were conducted by phone or zoom due to the Covid-19 pandemic and subsequent travel restrictions. All other interviews were conducted in person.

Interviews

In depth semi-structured interviews formed the main data collection method for the case studies. Interviews provided practical context-dependent knowledge that was essential to the development of the case studies (Flyvbjerg 2006). The benefit of semi-structured interviews is that the interviewer can ask follow-up questions in relation to verbal and non-verbal responses. Interviews with different stakeholders allowed a discovery of multiple realities yet were structured sufficiently to facilitate standardisation of the interview process (Almeida et al. 2017). In this thesis, evidence of these multiple realities is presented through quotes in the words of the different stakeholders and represents their range of perspectives (Creswell 2007). Interviews were a useful way to gather information from livestock producers, who may be less inclined to participate in quantitative surveys. Given the interviews were in-depth, fewer participants were needed to provide useful and relevant insights (Almeida et al. 2017). According to Zimmermann et al. (2010) interviews establish personal contact with people affected by livestock predation and demonstrate a willingness of conservation researcher practitioners to listen, an important step to reduce conflicts over wildlife. A limitation of in-depth interviews is that they are time and resource intensive, and results are not always generalisable (Almeida et al. 2017).

Interview sampling method

Two sampling procedures (purposive sampling and snowball sampling) were used to recruit interviewees. Firstly, purposive sampling enabled me to identify potential interviewees that were proficient and knowledgeable in the areas of extensive livestock production, wildlife management and/or carnivore conservation (Bryant and Charmaz 2010). Selection criteria were developed to aid this process as explained below. The emphasis of this sampling technique was on quality rather than quantity, with the aim to become 'saturated' with information on the topic (Morse 2015). Additional participants were identified using a snowball or network sampling technique (Biernacki and Waldorf 1981). These procedures yielded a varied sample of participants via referrals to various stakeholder groups such as government agents, NGO representatives and livestock producers, that would be difficult to reach without assistance (Etikan et al. 2016). This technique is useful to sample individuals from groups that are either reluctant to volunteer personal information or are geographically isolated from major cities (Sadler et al. 2010).

The use of probability sampling methods is considered as the gold standard for recruiting participants who are likely to be representative of the larger population from which they are drawn (Sadler et al. 2010). The key limitation of snowball sampling in a research context is that it is a non-probability method, that is it does not recruit a random sample (Sadler et al. 2010). Therefore, any findings or conclusions reached in this study may over-represent livestock producers who share similar characteristics, such as to not persecute carnivores. However, it should be noted that even probability-based sampling strategies have inherent bias.

A challenge I faced in undertaking a multi-country study was my limited familiarity all international actors in the field of human wildlife interactions in extensive grazing landscapes. This raised a risk of unintentionally excluding important stakeholders from the research. To manage this risk, I enlisted the help of strategic non-government organisations (herein intermediaries) in South Africa and the US to help identify suitable interview candidates. The risks associated with the use of intermediaries is the potential to introduce bias in the sample, however, this was mitigated by snowball sampling. The interview recruitment process was similar in South Africa and the US. The intermediary would contact a potential interview candidate, if the candidate signified interest, then their contact details would be passed to me. I would follow up by emailing the information sheet and consent form and arrange a suitable interview time. Most participants demonstrated an eagerness to participate and did not express any concern around trust in the research, researcher, or concerns that their information would be used without their permission. This process of making 'connection' was crucial for establishing trust between myself and the interviewees. In Australia, suitable interview candidates were identified through the contacts of my supervisors, via an internet-based search of government agencies, industry and NGOs, and snowball sampling.

Interview selection criteria

Selection criteria were developed to ensure that a variety of viewpoints would be canvassed in data collection. Table 3.

Table 3 outlines the selection of four key stakeholder groups and numbers interviewed. In total, 66 semi-structured interviews were conducted across the focal countries with representatives of four key stakeholder groups.

The largest sample group were commercial livestock producers that extensively graze sheep or cattle in rangeland ecosystems. However, livestock producers are not a homogeneous group, and have differing attitudes and perceptions about large carnivores as well as different strategies to reducing predation risk, as I acknowledge in Table 3.

Table 3: Stakeholder group description and number interviewed

Stakeholder group description	Number interviewed
Livestock producers, farm owners and managers comprised of: • **Innovative producers**: who primarily choose to use preventive non-lethal practices • **Conventional producers:** who primarily use lethal options	47 (31) (16)
Livestock industry representatives: industry funded organisations that represent the interests of livestock producers.	2
Government representatives: employed in agencies that govern natural resources i.e., responsibility to enact wildlife plans or represent agricultural interests i.e., staff whose responsibility it is to take calls from producers concerned about livestock predation or who have decision-making responsibility as to which type of option will be used (lethal or non-lethal) and funding allocations for these strategies.	10
Representatives from non-government organisations and wildlife researchers: Representatives from organisations involved in wildlife or carnivore conservation, animal welfare, predator or wildlife friendly labelling schemes. This also includes advocates and researchers who work directly with livestock producers with expertise in wildlife ecology, social science or non-lethal tools and practices.	7
Total	**66**

A further breakdown of stakeholder groups for each country is provided in Table 4 for South Africa, Table 5 for the US and Table 6 for Australia.

Sample sizes in qualitative research need to balance two factors. An adequate number of stakeholders to allow for finding variations in conceptions and ensure the data produced is manageable. To uncover the similarities and differences between the four stakeholder groups, my target sample size for the interviews was 65. Overall, the sample had a male bias, with 78 per cent of the sample male and 21 per cent female. This reflects the reality of gender bias in

agriculture, for example, in the US about 86 per cent of farm operators and 87 per cent of tenant farmers were male, and female farmers tended to generate less income per farmer than men (Horst and Marion 2019).

Interview process

The interview process was similar in each country. The interviews commenced with participants introducing themselves and giving an overview of their livestock operation or role in government or Non-Government Organisation (NGO) and interactions with large carnivores.

I developed an interview guide to structure the interviews (Schermelleh-Engel et al. 1987) (see Appendix 1). This guide also facilitated the organisation and analysis of the interview data. The length of the interviews varied between 60 and 90 minutes. Interviews were treated as conversations during which I drew out detailed information and reflections from the interviewees. Interviews were conducted in English although for some participants in South Africa, English was their second language. Interviewees were asked a range of open-ended questions with probing follow-up questions.

Interviews with livestock producers

Across the three countries (described in more detail below), I interviewed livestock producers; farm managers, and staff to elicit data about interactions between producer, livestock, large carnivores and other local wildlife, as well as perceptions about predation risk and strategies to reduce livestock predation. These reflections provide useful qualitative data for researchers (Bowen 2010). Interviews were divided into 3 parts:

- Part one: producers were asked generally about their livestock enterprise such as size of land holding; type and breed of livestock and why they were selected; numbers of livestock; and access to resources such as water points. Producers were asked about the season/s when livestock would have young and likely more vulnerable to predation.

- Part two: focussed on the interactions with local wildlife, specifically carnivorous or omnivorous species that inhabited or moved through the farm. Producers and staff were asked to recall human-carnivore-livestock interactions with questions focussing on whether any livestock predation events had occurred within the last two years. If so, this triggered further questions about the impacts of predation in terms of livestock welfare impacts such as stress, injury or death and whether this translated into a financial loss, as well as psychological impacts such as stress from anticipated or actual impacts on livestock and livelihoods. Producers were also asked about their attitudes to local carnivores to generally understand their degree of tolerance towards them.

- Part three: explored approaches to mitigating predation risks. Follow up questions were triggered depending on whether producers used predominantly lethal options (shooting, trapping, poisoning), non-lethal options (aversive options, guardian humans or animals, livestock husbandry etc) or mixed approaches. For example, if producers relied on lethal options, they were asked questions about who carried out the lethal control (the producer, employees or government agents) and when a lethal option was executed, such as pre-emptively or only after a predation occurred. Producers that chose primarily non-lethal options were asked about why they chose those options, the barriers they faced in using those options such as social pressure from other producers or their local communities and how they managed that pressure. All producers or staff were asked to judge the effectiveness of predation mitigation approaches and why they considered their preferred approaches worked to reduce predation loss.

A number of producers had switched from predominantly lethal options to non-lethal options to mitigate predation risk. This transformation was often expressed as a result of their reflection on the effectiveness of predation mitigation strategies, the wider environmental or social impacts and networks of support or resources they had drawn on. Their stories of transformation offered insight into barriers, hurdles or constraints to change, as well as the processes, events and conditions which precipitated, facilitated and enabled change to occur. These insights were critical to chapters six and seven focussed on barriers to adoption of preventive innovations. Interviewees were asked to reflect on the available supports and incentives for preventative innovations, and sources of information and ecological stewardship more broadly. Interviews concluded with the interviewees being asked about their vision for agriculture for the year 2040.

Interviews with government and non-government organisations (NGOs) and researchers

Interviews were conducted with staff from environmental or animal protection NGOs, researchers and ecologists. Interviews were critical to provide a high-level overview and context to human-carnivore conflict, such as species implicated in conflict, ecology and behaviour of these species, and how species are managed. NGOs were asked to reflect on the efficacy of each option ranging from lethal to non-lethal, and the context in which options would be most successful to reduce predation risk. As well as ways that NGOs support producers to transition from lethal to non-lethal options, barriers producers face in adopting non-lethal tools and practices, and leverage points to foster coexistence. Interviews concluded with questions regarding their vision for carnivore management out to the year 2040.

Interviews with government organisations

Interviews were conducted with key decision makers from government departments that govern both agriculture and conservation such as:

- United States Department of Agriculture- Wildlife Services, Office of Species Conservation, Department of Fish and Wildlife in the US;

- Department of Rural Development and Land Reform, Western Cape province and Agri Eastern Cape Province in South Africa; and

- Local Land Services in NSW, Department of Environment, Land, Water and Planning (DELWP) in Victoria and Primary Industries and Regions South Australia (PIRSA).

Interviews touched on roles and responsibilities of government departments; wildlife management plans and laws that govern wildlife; institutional capacity building activities such as information provision, training, financial support, personnel provided for both lethal and non-lethal carnivore management; and how government policies and laws impede or enable the adoption of preventive innovations and coexistence more broadly. This information helped to identify potential leverage points of change such as the critical factors that facilitate adoption of coexistence tools and practices, the role of the government in bringing about change on these issues, the barriers to implementing change, and year 2040 vision.

In Australia, interviews were also conducted with livestock industry representatives to gain a deeper understanding of grazing industry perspectives as well as the institutional context around predator management.

Field observations

Going to the 'field,' where the people live and work provided important context to understand each stakeholders' view, and historical and cultural contexts (Creswell 2007). Field observations were taken opportunistically on farms, usually conducted before or after an interview in South Africa and the US. According to (Almeida et al. 2017 p 376) "*observation is a systematic process of collecting information, in which researchers observe a given phenomenon in their natural environmen*t". This approach is one of the more reliable ways to obtain data on the behaviour of people and animals (Almeida et al. 2017). While it can be challenging to document observations (Almeida et al. 2017), data were recorded via photos and field notes and contributed generally to the development of the case studies.

The field trips primarily involved observing the paddocks where extensive livestock grazing took place and the setup of non-lethal deterrents to see how they worked. For example, in the US this involved observing the kinds of fencing or guardians such as herders or dogs. In South Africa, it involved observing how the short-term high density grazing system worked with multiple small paddocks, or the landscape condition before and after managed grazing. Opportunities for field observations in the Australian case study were heavily constrained by COVID-19 restrictions on travel and face-to-face contact with research participants. Yet this was not a concern as field observations were only supplementary to the case study data collection through interviews.

Policy document review

I also conducted a strategic document review to provide greater context to policy, wildlife management plans and trends (such as biodiversity or lethal control) across the three countries, including:

- the National Wild Dog Action Plan (Australia) (Australian Wool Innovation 2020) , NSW Wild Dog Management Strategy (NSW Department of Primary Industries 2017) and biosecurity relevant legislation (Australian Govenment 2014; NSW Government 2015),

- the Oregon Wolf Plan (US) (Oregon Department of Fish and Wildlife 2014) and USDA reporting on the numbers of wildlife killed across the US by Wildlife Services (APHIS 2020).

- State of South Africa's Biodiversity report (South African National Biodiversity Institute 2012) and Agriculture: Facts and Trends (Goldblatt 2011).

Lastly, I reviewed NGO guides about carnivores on livestock farms that focus on how to prevent livestock predation developed by Defenders of Wildlife in the US (Edge et al. 2016) and the Landmark Foundation in South Africa (Smuts 2008).

3.3.3 Stage 1: Data collection for South Africa case study

Southern African workshop

In January 2018, I co-hosted a workshop on human-carnivore coexistence in multi-use landscapes at the Pathways Africa conference in Windhoek, Namibia (southern Africa). The conference theme was 'Living with Wildlife' and attracted an international audience primarily wildlife conservation practitioners and researchers, government representatives and pastoralists. Workshop participants were asked to register for the workshop and give informed consent to participate (see section 3.6 Ethics for more detail). The workshop had 40 participants: 21 females and 19 males. Participants represented 7 different countries: Namibia, South Africa, Tanzania, Botswana Zambia, the US and Canada.

Participants were divided into two groups where they worked through a series of questions to determine firstly, the current business-as-usual (herein BaU) context of human-carnivore interactions in rangeland systems. Secondly, factors that drive change in the BaU context or keep BaU system in place were canvased. Thirdly, participants developed a tangible vision for a desirable transformed future conceptualised in the year 2040. Lastly, they explicitly considered alternative approaches that later formed transition pathways to move from the current system to a transformed social-ecological system. The workshop yielded data that formed the basis of two conceptual models of transformative change described in detail in Chapter 5. The workshop information supplemented and was verified by key informant interviews in South Africa and the US.

Stakeholder interviews in South Africa

In total 20 semi-structured interviews were conducted across South Africa. Table 4 outlines the spread of interviewees to ensure representation across key stakeholder groups. The interviews were conducted face to face primarily on farms in 3 provinces in South Africa (Western, Eastern Cape and Northern Cape Provinces). These provinces were selected because of the vast allocation of land devoted to extensive livestock grazing and history of human-carnivore conflict with leopards, black-backed jackal and caracal. In total, 17 males and 3 females were interviewed. Of the 16 livestock producers that were interviewed, 9 were classified as innovative and 7 were classified as conventional producers per the selection criteria.

Table 4: Classification of stakeholders interviewed in South Africa and totals

Stakeholder classification	Total
Non-Government representatives and wildlife researchers • Landmark Foundation, Western Cape province	2
Government representatives • Department of Rural Development and Land Reform, Western Cape province • Agri Eastern Cape Province	2
Livestock producers and staff involved in extensive grazing of sheep or cattle • Innovative producers • Conventional producers	9 7
Total	**20**

3.3.1 Stage 2: Data collection for western United States case study

Stakeholder interviews in the United States

I conducted a total of 25 interviews were conducted in the US across the four stakeholder groups, shown in Table 5. Most of the interviews were conducted in person with two conducted over the phone. Interviews were conducted across four states: Oregon, Idaho, Montana and California. This approach provided a geographical spread of participants and facilitated an understanding of the differences in the way US states manage carnivores. Of the 25 interviews, 19 identified as male and 6 identified as female.

Table 5: Classification of stakeholders interviewed in the US and totals

Stakeholder classification	Total
Non-Government representatives and wildlife researchers • Defenders of Wildlife • Wildlife Friendly Enterprise Network • Blackfoot Challenge Montana	3
Government representatives • Office of Species Conservation, Idaho • Wildlife Services - Wolf recovery coordinator for Idaho • Blane County Commissioner, Idaho • Oregon Department of Fish and Wildlife • State Director USDA Wildlife Services Montana • Montana Fish, Wildlife and Parks	6
Livestock producers and staff • Innovative producers • Conventional producers	12 4
Total	**25**

US workshop

In October 2019, I attended the 2-day Human-Wildlife Coexistence Summit hosted by US NGO Defenders of Wildlife. The summit had 95 participants, including biological and social scientists, and wildlife and agricultural specialists (i.e., ranchers and managers, state, federal and tribal government policy makers and practitioners). The workshop had a more even gender balance with 43 females and 52 males. The summit allowed me to meet key interviewees with in-depth subject knowledge about human-wildlife coexistence.

International case study analysis

The data gathered from Stages 1 and 2 was critical in answering the research sub-questions:

- *What are the key pathways towards human-carnivore coexistence in the South Africa and the western US?*

- *What are the major barriers that limit the adoption of preventive innovations in the US and how do these barriers operate?*

The data were synthesised into two models that depict transformation in Social-Ecological Systems in chapter five. A transformation model template (see page 72 Chapter five) based on the 'three-horizons' approach used in futures work that connects the present (horizon 1) with emerging innovations (horizon 2) and visioning divergent futures based on a set of values (horizon 3) was used to frame the discussions (Curry and Hodgson 2008). Information gathered from the stakeholders was used to populate the four components of the transformation models (i.e., drivers of change, business-as-usual, transition pathways and the transformed system) (Jacobs et al. 2017). Change to a desirable transformed future (in the year 2040) was conceptualised as a series of transition pathways that emerge from current practice either through existing innovations or from drivers of change. The two models provide critical information (envisioning and sensemaking) that can be used by change makers in the phase *Preparing for transformation* (Moore et al. 2014)*.* The models map out various pathways (options) and can be used to inform decisions about selecting which pathway to invest in and providing critical information for *Navigating the transition* phase (Moore et al. 2014)*.*

The interview data provided valuable insight into the barriers to the adoption of preventive innovations detailed in chapter 6. Supporting the adoption of preventive innovations is a central way that environmental and animal protection NGOs can facilitate coexistence. The three spheres of transformation framework O'Brien (2018) was used to classify the barriers to adoption in the practical, political and personal spheres, recognising that the boundary between each of the spheres is porous and there is overlap between them. Yet this classification was useful to understand how the barriers operate and uncover which sphere or spheres creates the greatest resistance to the adoption of preventive innovations to foster coexistence.

3.3.2 Stage 3: Data collection for Australian case study

Stakeholder interviews in Australia

Table 6: Classification of stakeholders interviewed in Australia and totals

Stakeholder classification	Total
Non-Government representatives and wildlife researchers • Livestock Guardian Dog researcher, Australian Capital Territory • Humane Society Australia, New South Wales • Australian Dingo Foundation, Victoria	3
Government representatives • Biosecurity officer Local Land Services, New South Wales • Department of Environment, Land, Water and Planning, Victoria • Primary Industries and Regions South Australia	3
Livestock producers and staff • Innovative producers • Conventional producers	8 6
Industry representatives • Center for Invasive Species Solutions (CISS) • Australian Wool Innovations (AWI)	2
Total	**21**

These interviews collected data of relevance to the Australian context to address research sub-questions 1-3 and to extend the analysis to address sub-question 4:

- What is the rationale for building human-carnivore coexistence in rangeland ecosystems?
- What are the key pathways to foster human-carnivore coexistence in Australia?
- What are the major barriers that impede the adoption of preventive innovations and how do they operate across Australia?
- What are the leverage points to facilitate adoption of preventive innovations by the Australian grazing industry?

The fourth sub-question was to assist in the synthesis of recommendations to promote human-carnivore co-existence in Australian rangelands grazing systems discussed in chapter 8.

3.4 Data analysis

With the participants' consent each interview was recorded and transcribed verbatim. Inductive thematic analysis Creswell (2007) of the interview transcripts was conducted using repeated coding, sorting, and categorising in MAXQDA software (VERBI GmbH version 18.2.0) qualitative analysis software (Miles and Huberman 1994; Creswell 2007). In inductive coding, the codes and themes derive from the content of the data (Braun and Clarke 2012). Coding helps to identify and provide a label for a feature of the data, thereby enabling researcher to review the whole of the data by identifying its most significant meanings (Miles et al. 2014). A

combination of codes was used based on participants' language and concepts and research questions (Braun and Clarke 2012). The transcripts were coded line-by-line (Saldaña 2009) into 32 different codes. A good code is one that captures the qualitative richness of the phenomenon (Boyatzis 1998).

I used the Miles and Huberman (1994) model for the thematic analysis process, that consists of three phases: firstly, *data reduction*; secondly, *data display* and thirdly, *data conclusion-drawing*.

Data reduction

In the data reduction phase, I undertook a comprehensive process of data coding in which I read and re-read the data to become familiar with it, then made logical associations with the interview questions, and considered what I had learned during the literature review and policy document analysis. I coded the South African interview transcripts and documents first in April/May 2018 and then the US transcripts between October 2019 to October 2020. Based on new codes that had emerged from the US data I went back and refined the coding of the South African data. I used 20 codes in total.

I coded the Australian data between April to June 2020 then in February 2021. Each code was constantly compared to all other codes to identify similarities, differences, and patterns. This phase also included highlighting poignant quotes from across all of the interviews that either captured a key theme or answered the research questions by taking excerpts from the participant's full text. I read each transcript again to compare, contrast and/or search for missing information that had not appeared in the first level of the themes (Ryan and Bernard 2003). Then I went through a process of removing redundant codes.

Data display

The data display phase entails the organised and compressed assembly of information to arrange concepts, identify patterns of meaning and either draw conclusions or move on to the next phase of analysis (Miles and Huberman 1994). This allows the researcher to see and make sense of collective or shared meanings and experiences (Braun and Clarke 2012). The analysis then shifted from codes to themes. At this stage I had gathered all the evidence from the three countries and then organised and grouped the data and codes into similar themes. A theme represents some level of patterned response or meaning within the data set (Braun and Clarke 2012). Using MaxQDA software I could retrieve codes or clustered codes to check how they related to the themes. I then explored the relationship between themes and considered how themes when combined could tell an over-all story about the data. This phase involves a recursive process whereby the developing themes are reviewed in relation to the coded data and entire data set to 'quality check' the analysis. The themes were clustered under headings that directly related to the research questions. Similarities and differences between separate groups of data (producers, conservationists, government representatives) clearly emerged at this stage. Themes within each data group were also beginning to cluster, with differences identified between the responses of groups that varied by stakeholder group. The nine major emergent themes, rooted in the evidence, provided by the data presented in the findings chapters 4 to 7.

The nine major themes included:

- **Predation mitigation strategies** – lethal and non-lethal or mixed, which was further explored in sub-themes such as reflections on effectiveness of each strategy, time of year when strategies are used and why (i.e., lambing or calving or when carnivores are active);
- **Business-as-usual context** for each country in relation to carnivore management;
- **Drivers of change** that influence business-as-usual, including a rationale for coexistence;
- **Pathways for human-carnivore coexistence** including sub themes such as preventive innovations, research, supports, capacity building, labelling programs;
- **Envisioning a transformed future** for each case study, with sub themes for producers, institutional representatives, conservationists and researchers;
- **Barriers to adopting preventive non-lethal innovations**, with sub themes such as practical implementation issues, social pressure, culture, laws, and institutional policies and supports and lock-in traps;
- **Institutional information** including sub themes of specific laws, processes to identify depredation, and industry policy;
- **The journey of innovative producers** and their distinguishing traits in terms of values, worldviews, identity; and
- **Key leverage points** for transformation towards coexistence.

Data conclusion-drawing

The final phase of the analysis comprises data visualisation and conclusions (Miles and Huberman 1994). I visualised data through quotations, narrative text, two change models and a discussion that compared differences and similarities between the three cases (Miles and Huberman 1994). In chapters six and seven quotes from interviewees are presented to provide evidence, support and validation of interpretations such as the existence of lock-in traps.

Limitations occur in all studies, and because of the nature of a doctoral study, the data were coded, and themes identified in the data by one person. However, I engaged in the inquiry with an awareness of my worldview, and ontological stance, thereby with self-awareness of the implications of my chosen methodology. As well, the analysis of the data and major themes were discussed with both supervisors and critical stakeholders and friends.

3.6 Ethical considerations

Human research ethics approval was granted by the University of Technology Sydney (ETH18-2568— HREC) in May 2018 to cover all three phases of case study data collection. No issues with ethics arose during the course of this thesis. I sought to de-identify the interview participants and keep their stakeholder classification when directly quoting them.

Chapter 4: Transitioning towards human – large carnivore coexistence in extensive grazing systems

In this chapter I provide four rationales for human-carnivore coexistence in rangelands grazing. This research was published in the peer-reviewed journal Ambio in May 2020. This chapter addresses research sub-question 1 by establishing the rationale for human-carnivore coexistence in extensive, commercial livestock production in rangelands ecosystems.

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PERSPECTIVE

Transitioning towards human–large carnivore coexistence in extensive grazing systems

Louise Boronyak ⓘ, Brent Jacobs, Arian Wallach

Abstract In light of escalating threats to biodiversity, conflicts between humans and large carnivores in production landscapes must be resolved. We explore how interactions between humans, large carnivores, and livestock can be modified to promote coexistence. We identify four rationales for building coexistence capacities in extensive rangeland livestock production systems: (1) livestock production is a dominant terrestrial land use; (2) large carnivores provide critical contributions to ecological functions; (3) the persecution of large carnivores has high ethical, welfare, reputational and social costs; and (4) a growing body of evidence shows that lethal control can be counterproductive to reducing predation risk. Two key leverage points to foster human–carnivore coexistence are the adoption of preventive non-lethal innovations, and the creation of an enabling environment. Leverage points must be appropriate at the local landscape scale and contribute towards global efforts to conserve large carnivores.

Keywords Human–wildlife conflict ·
Large carnivore conservation · Predator friendly farming ·
Social ecological systems

INTRODUCTION

Rangelands are the most extensive land cover type globally, covering half of the land surface and representing a variety of ecological systems including drylands, grasslands, savannah and shrublands (Davies et al. 2015; Briske 2017). Rangelands are important for human food security and wellbeing, and also for biodiversity conservation, and are therefore thought of as Social Ecological Systems (SES) (Davies et al. 2015). SES are dynamic, complex and involve various interactions between humans and natural systems (Holling 2001; Biggs et al. 2015; Stern 2018). This paper discusses interactions within rangeland systems between large carnivores ($\geq$ 15 kg), domestic cattle and sheep livestock (hence *livestock*), and humans that raise livestock for their livelihoods (hence *producers*).

We focus on Australia, South Africa and the United States of America (USA), three countries that have vast rangelands used for extensive livestock grazing (Havstad et al. 2007; Smith et al. 2007; Palmer and Bennett 2013). Livestock production in these countries is primarily commercial rather than subsistence in nature and is largely reliant on grazing of low-input or non-cultivated vegetation. Rangelands are known for human–wildlife conflict as they are less modified than other landscapes and support multiple uses such as agriculture, recreation and habitat for wildlife. Large carnivores in rangeland systems include dingoes (*Canis dingo*) in Australia; leopards (*Panthera pardus*) in South Africa; and wolves (*C. lupus*), coyotes (*C. latrans*) bears (*Ursus* spp.), and cougars (*Puma concolor*) in the USA. These carnivores often hunt large prey and their territories are large, which increases the likelihood of encounters with livestock (Treves and Karanth 2003; Zimmermann et al. 2010).

Rangelands are principally managed to maximise yield for domesticated herbivores and to reduce ecological variation (Briske 2017). Rangeland management includes carnivore persecution, altered fire regimes and fencing combined with sustained grazing of livestock. This established regime has led to degradation, desertification, biodiversity loss, and associated losses of ecosystem services such as water cycling and carbon sequestration (Havstad et al. 2007; Briske 2017). Using a systems approach to consider human–livestock–carnivore interactions can offer insights about how to create desirable transitions in rangeland SES (Biggs et al. 2015; Stern 2018). The pursuit

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of desirable transitions in SES is important in light of a growing human population, rising meat consumption, and declining biodiversity.

Human relationships with large carnivores range from tolerance and coexistence to intolerance and persecution. Tolerance is the acceptance of the perceived costs and benefits of living alongside local populations of wildlife (Bruskotter and Fulton 2012; Kansky et al. 2016). Coexistence is a dynamic but sustainable state in which humans and wildlife co-adapt to living in shared landscapes (Oriol-Cotterill et al. 2015; Carter and Linnell 2016). Coexistence is often conceptualised as focussing exclusively on wildlife, yet to gain broad acceptance this perspective must be broadened to include the human dimension (Madden and McQuinn 2014). Positive interactions between producers and large carnivores encompass both tangible (monetary, ecological, social, animal welfare) and intangible (cultural or spiritual) values. For example, large canids such as dingoes and wolves are appreciated by individuals and communities for their ecological, aesthetic, spiritual and cultural (Kellert et al. 1996; Smith and Litchfield 2009; Ripple et al. 2014), as well as for their intrinsic value (Wallach et al. 2018). In contrast, negative interactions incur a harm or cost, in the form of the real or perceived threat posed by large carnivores to producers (stress and financial loss; injury or mortality of domestic animals), but also a harm to carnivores from intolerance, persecution, and eradication of carnivores (Graham et al. 2005; Dickman et al. 2011). Persecution is carried out at multiple scales, from farm to region or state scale in the form of government lethal control programmes (Berger 2006; Wallach et al. 2017; Gordon 2018). Persecution, in this context, is based on the contested view that livestock depredations and conflicts will decrease when lethal control of wild predators is increased (Wielgus and Peebles 2014).

Promoting coexistence between humans and large carnivores would, we believe, benefit from expanding from a narrow focus on negative interactions alone, to a holistic discourse which also recognises opportunities for positive interactions and mutual benefits. While the term 'human–wildlife conflict' is widely used to describe negative interactions, it fails to capture the complexity of interactions (Messmer 2000) and limits our ability to recognise opportunities for positive interactions. Peterson et al. (2010) argued that the term human–wildlife conflict is detrimental to fostering coexistence with wildlife because it represents the interaction as a conscious antagonism rather than the result of competition over limited resources. Focus on negative interactions can create confirmation bias, which limits the desire to seek out information about human–carnivore coexistence and novel approaches to reduce predation risk (Jonas et al. 2001; Young et al. 2015).

Here, we use the term *negative/positive human–carnivore interactions* to promote language more enabling of coexistence.

REASONS TO TRANSITION TOWARDS HUMAN–CARNIVORE COEXISTENCE

We offer four reasons to transition towards human–carnivore coexistence in rangeland systems: livestock production dominates global land use; carnivores perform important ecological functions; carnivore persecution incurs a high ethical cost; and growing body of evidence shows that lethal control can be counterproductive to reducing predation risk. We then discuss key leverage or intervention points that can facilitate a shift towards coexistence in SES and more positive human–livestock–carnivore interactions in extensive livestock production systems (Meadows 1999). These leverage points may be applicable to extensive grazing systems outside of rangelands areas.

Livestock production dominates global land use

Livestock grazing occupies an estimated 37% of the world's ice-free land, predominantly in rangelands (Ferrier et al. 2019), which produce ∼ 10% of the global meat supply (Alkemade et al. 2013). Rangeland vegetation supports both the livestock industry and a diversity of wildlife (Davies et al. 2015). Extensive grazing occurs in systems that are less modified and more biodiverse than intensive agricultural systems (Scherr and McNeely 2008). However, the combination of the growing human population, urbanisation and rising affluence is increasing the demand for meat products, which is projected to increase by 57% by 2050 (Mottet et al. 2017). A large proportion of wildlife in the landscape has been replaced by livestock, contributing to biodiversity loss (Machovina et al. 2015; Bar-On et al. 2018). The pressure to expand the global footprint of livestock production to meet demand will likely increase encounter rates between carnivores and livestock (Treves and Karanth 2003; Treves 2009; Ripple et al. 2014). These factors mean that to meet the needs of humans and of the many other beings that depend on healthy rangelands, sharing landscapes is a strategy that has the potential to achieve human and more-than-human (conservation) values.

Large carnivores provide critical ecological functions

Carnivore conservation is increasingly considered a priority, as globally 77% of the world's large carnivores are

undergoing population decline and 61% are threatened (Ripple et al. 2014; Lennox et al. 2018; Ferrier et al. 2019). Large carnivores maintain the function of diverse ecosystems via direct and indirect interactions with other predators and prey that help sustain species abundance and richness (Ripple et al. 2014). Large canids, such as wolves and dingoes, influence ecosystem processes by limiting the abundance of wild herbivores, such as deer (family Cervidae) and kangaroos (*Macropus* spp.), thereby reducing or shifting grazing pressure on vegetation (Ripple and Beschta 2007; Letnic et al. 2012). Large carnivores can benefit livestock industries by limiting negative impacts from mesopredators as well. For example, the dingo, Australia's largest mammalian carnivore suppresses red fox populations (*Vulpes vulpes*) in rangelands (Letnic et al. 2009) and changes fox behaviour through increased vigilance (Leo et al. 2015). Dingoes promote vegetation biomass and diversity (Wallach et al. 2010), which can benefit livestock through reduced competition for food and water, which in turn may increase cattle producer profit margins (Prowse et al. 2015). The dingo's social stability and associated behaviours are key to its ecological functions (Wallach et al. 2010). Similarly, after the reintroduction of grey wolves into Yellowstone National Park, USA in 1995 the increasing density of wolves reduced the total grazing pressure in the park on flora including aspen and cottonwood (*Populus spp.*) and willow (*Salix spp.*) (Ripple and Beschta 2012). These trophic cascades result not only from the number of prey that are hunted, but by the efforts of the prey to avoid encounters with predators. Predator avoidance behaviour alters the time and location of grazing by prey species by creating a 'landscape of fear' (Laundré et al. 2001), which limits the length of grazing of vegetation and may benefit other wildlife (Ripple and Beschta 2007). Reducing carnivore persecution, therefore, can play a vital role in conserving a range of threatened species and contribute to the 'bigger picture' efforts to improve the ecological sustainability of livestock production and regenerative agriculture (White 2012; Thorn et al. 2015; Johnson and Wallach 2016). The successful integration of conservation and production in agriculture provides a sustainable and economically profitable way forward and helps address the current biodiversity crisis (Fischer et al. 2006; Ferrier et al. 2019).

Ethical, welfare and social costs of persecuting carnivores

Large carnivores are sentient, possess sophisticated capacities for emotion, consciousness, and sociality, and are thus moral subjects whose interests as individuals should be protected (Wallach et al. 2018). Large carnivore persecution has high ethical costs that are increasingly incurring high social, economic, and industry reputation costs as well (Treves and Karanth 2003). The trapping and shooting of large carnivores across rangelands of the USA and South Africa, and use of poison baits in Australia remains widespread (Berger 2006; Machovina et al. 2015; McManus et al. 2015b; Smith and Appleby 2018; Philip 2019). Objections to persecution have been raised due to ethical concerns that encompass negative animal welfare (suffering) and conservation outcomes (Littin and Mellor 2005; Zimmermann et al. 2010; Ramp and Bekoff 2015; Bergstrom 2017; Wallach et al. 2018). Lethal control programmes frequently circumvent animal welfare legislation by labelling wildlife as 'pests' with treatment often justified on utilitarian grounds (Ramp and Bekoff 2015). Despite efforts to reduce animal welfare concerns, lethal methods of control cause pain, distress and death to both target and non-target wildlife and domestic animals (Littin and Mellor 2005; Fleming et al. 2014; Philip 2019). In addition, lethal control programmes have a range of intangible costs such as political backlash from citizens, environmental and animal welfare groups that have flow on effects to the grazing industry (Treves and Karanth 2003).

The social costs of carnivore persecution can translate into financial impacts on the grazing industry through consumer preferences and the costs of lethal control. Increasingly, businesses require the approval of the general public to continue to operate, that is, a 'social license' (Williams and Martin 2011). The rise of social media provides consumers with a powerful tool to voice concerns that influence industry reputation and viability. Social license issues for extensive livestock grazing encompass animal welfare, environmental sustainability, health and nutrition, ethical treatment of workers, fair trade and corporate accountability (Grunert 2006; Meat and Livestock Corporation 2010; Napolitano et al. 2010). An increasing segment of consumers demands that food and fibre are produced in a way that is healthy, environmentally sustainable, ethical and incorporates practices that promote good animal welfare (Hustvedt et al. 2008; Napolitano et al. 2010). Animal and environmental protection NGOs highlight areas where livestock production could reduce impacts on domestic and wild animal welfare and improve environmental sustainability. The Australian livestock industry has responded to other threats to its social license by actively seeking to improve sustainability. The industry has set a net zero emissions target by 2030 and established the 2018 Australian Beef Sustainability Framework that follows the global trend towards addressing environmental concerns in beef production such as Global Roundtable for Sustainable Beef (grsbeef.org). With sufficient consumer pressure, this shift is likely to eventually extend towards requiring greater protections for large carnivores in rangelands.

Lethal control of large carnivores is counterproductive to reducing predation risk

There is mounting evidence that killing large carnivores is counterproductive to reducing predation risk especially when applied unselectively at a population level (Berger 2006; McManus et al. 2015a; Treves et al. 2016; Stone et al. 2017; Wallach et al. 2017; van Eeden et al. 2018). While lethal control may provide a temporary reprieve for producers in some circumstances (Bradley et al. 2015), it does not provide a permanent solution as it fails to address the underlying cause(s) of predation risk (Treves and Naughton-Treves 2005; Stone et al. 2017). Killing carnivores does not necessarily reduce carnivore populations, because persecuted populations have higher reproductive and immigration rates (Wallach et al. 2010). Predation losses impact producer profitability, yet simply removing carnivores does not automatically improve farm viability, which is more closely correlated with input costs (feed and wages) and market conditions (i.e. higher lamb prices) than predation losses (Berger 2006). Furthermore, predation can be a minor cause of mortality compared to other preventable causes, such as poor husbandry practices (Wallach et al. 2017). A growing body of research calls into question the necessity of lethal control to reduce negative human, livestock and carnivore interactions. Non-lethal methods are potentially more effective and may cost less than lethal methods (McManus et al. 2015b; Treves et al. 2016; Stone et al. 2017; van Eeden et al. 2018; Wallach et al. 2018). For example, McManus et al. studied a group of 11 farmers in South Africa and found that lethal control of carnivores was overall more expensive and significantly less effective than non-lethal control over a 3-year period. In some cases, lethal control has been used to selectively manage individual carnivores that repeatedly predate on livestock as a means to placate individual producers (Treves and Karanth 2003). However, tolerance for carnivores can also be built by collaborating with and supporting producers that want to adopt locally appropriate preventive innovations that protect livestock and producer livelihoods but not at the expense of large carnivores.

DISCUSSION

Leverage points for coexistence between humans and large carnivores

Learning to build coexistence with carnivores in production systems provides an opportunity to build human capacity to resolve conflicts with wildlife peacefully in a range of other contexts. Attempting to find ways for humans and large carnivores to coexist is challenging because it is entangled with social values, identity, distrust, conflicts and inertia (Madden and McQuinn 2014; Stern 2018). Identifying leverage or intervention points can help identify where a relatively small change in practice can lead to large shifts in the behaviour of SES (Meadows 1999).

Meadows (1999) framework presented 12 leverage points to facilitate change in systems ranging from the least effective leverage point of altering constants, parameters and numbers, through to shifting mindsets and transcending paradigms, which are regarded as the most effective leverage points to create change in complex systems. This framework provides a promising approach for conceptualising transformation in SES because it provides a holistic view of system elements and their interrelationships (Abson et al. 2017). O'Brien (2018) modified Meadows' framework to consider how to achieve the deep transformational change required to meet the global climate change target of 1.5° celcius. O'Brien's framework considers leverage points across three spheres: practical, political and personal. The practical sphere covers specific interventions, actions, strategies and behaviours that directly and practically contribute to desired outcomes (O'Brien 2018). The political sphere is where policies and institutions influence the systems and structures that enable or constrain practical responses. In any contested space, interest groups lobby to maintain the status quo at the same time as social norms are challenged leading to the formation of new social movements (O'Brien 2018). The personal sphere or 'inner worlds' encompasses thoughts, values, beliefs, identities and emotions and is a deep leverage point as it has the power to influence individuals' worldview of the system and subsequently how they behave (Meadows 1999; Ives et al. 2020).

Activating practical, political and personal leverage points can assist the transition towards human–carnivore coexistence in rangeland systems. In the practical sphere, there are a variety of tools and methods that can proactively reduce predation risk that are also non-lethal (i.e. do not cause injury or death) to wildlife (Stone et al. 2017; Wallach et al. 2018). From the political sphere, the creation of an enabling environment for coexistence draws on key stakeholder input and improvements in governance of the spaces where livestock production and wildlife interact. Both practical and political leverage points are powerful as they have the potential to influence the personal space in the form of worldviews. According to the concept of 'chains of leverage', one type of change in a system can precipitate another across different depths of leverage (Fischer and Riechers 2019).

The practical sphere: Non-lethal preventive innovations

Preventive innovations cover a range of practices intended to improve conservation outcomes in landscapes used for agriculture. Adoption of such practices can deliver significant public benefits, including biodiversity conservation (a public good), but may incur a cost or may not immediately benefit the producer (Pannell and Vanclay 2011). Preventive innovations can achieve a range of goals in the practical sphere and can also influence perception of large carnivores in the personal sphere (beliefs about carnivores). For example, non-lethal tools and methods are preventive innovations because they are preferable from ethical, social, conservation and animal protection standpoints. Preventive innovations also contribute towards producer goals (protecting livestock, industry reputation, profitability and livelihood) by reducing predation risk to more tolerable levels (McManus et al. 2015b; Carter and Linnell 2016; Johnson and Wallach 2016; Treves et al. 2016; Stone et al. 2017; Wallach et al. 2018).

Preventive innovations generally focus on three key areas: deterrents, enclosures, and improved husbandry. Preventive innovations when applied to predators fit under the realm of Predator Smart Farming more commonly referred to as Predator Friendly Farming. Deterrents (visual, audio, chemical) discourage carnivores from areas that are used for livestock grazing to reduce encounter rates and predation risk (Callahan et al. 2003). Visual deterrents take the form of flashing lights at night to mimic human presence or fladry (strips of brightly coloured material on wire around livestock enclosures) which plays on the neophobia of wolves (Stone et al. 2017). Fladry can also be electrified ('turbo fladry') as an additional aversive stimulus to deter carnivores that come close to livestock enclosures (Young et al. 2019). Audio deterrents use sounds to frighten or startle a carnivore (e.g. music, sirens, horns or ultrasonic devices). Enclosures, ranging from permanent fencing, electric fencing, to moveable barriers such as night pens and kraals, create a physical barrier between the carnivore and the domestic animal (Callahan et al. 2003; Wilson et al. 2005). Husbandry practices include the use of guard humans (e.g. herders and range riders to check and herd livestock), guard animals (e.g. dogs, donkeys, llamas), the removal of attractants (e.g. treating ill or injured livestock and removing carcasses), and the use of various grazing strategies (e.g. high intensity, short duration grazing) involving human presence in the landscape and tightly herding livestock together (White 2012).

Research regarding the efficacy of preventive innovations is growing along with its application to various livestock production systems; however, adoption remains limited (McManus et al. 2015b; Johnson and Wallach 2016; Treves et al. 2016; Stone et al. 2017; van Eeden et al. 2018). van Eeden et al. (2018) identified livestock guardian dogs and fladry as the most effective forms of preventive innovations and more effective than lethal control. Consequently, preventive innovations have been advocated by environmental and animal protection groups for improved carnivore conservation and welfare outcomes. However, some producers feel resentment towards these groups and their attempts to educate and impose practice change on their livelihoods, particularly if the changes do not align with local social norms and culture (Treves et al. 2006). Adoption is complex and decisions by producers whether to adopt an innovation or change of practice are influenced by how and by whom a message is communicated, e.g. whether they are a trusted and credible source of information (Rogers 2003; Stern 2018). The transition in the adoption of preventive innovations from niche to mainstream needs to be supported by an enabling environment that encourages experimentation with and adaptation of innovations to the local environmental, social and financial context.

The political sphere: Creating an enabling environment for coexistence

An enabling environment can be fostered through effective governance, which incorporates a range of values including carnivore persistence, social legitimacy, and livelihood sustainability. These values are fostered through conflict mitigation and engagement processes that enable respectful dialogue and build trust between stakeholders (Treves and Naughton-Treves 2005; Carter and Linnell 2016). The central aim of environmental governance is to maintain or improve "the ability of environmental systems to function and to produce ecosystem services through the persistence of species, habitats or biodiversity" (Bennett and Satterfield 2018, p. 7).

Livestock grazing is a socio-cultural practice shaped by the political sphere that influences social norms or societal expectations about behaviours that are acceptable or discouraged. Socio-cultural practices are enforced through informal and formal institutions through rejection or reward (Polski and Ostrom 1999; Pretty and Smith 2004; O'Brien 2018). Although the paradigm is shifting, social norms relating to carnivore persecution in many countries remain reinforced by legislation, funding and government programmes that focus on lethal control (Treves and Bruskotter 2014; Philip 2019). This further entrenches killing carnivores as acceptable and normalised (Wallach et al. 2018; Phillip 2018) and constrains the adoption of preventive innovations (Knowler and Bradshaw 2007).

New models of partnerships have the capacity to influence the political sphere to facilitate a just transition

towards human–carnivore coexistence in rangelands. For example, in Montana, USA, a partnership between the government's Wildlife Services (WS), Montana Livestock Loss Board and environmental NGOs including the Natural Resources Defense Council (NRDC), Defenders of Wildlife (DOW) and the Vital Ground Foundation, has increased the implementation and acceptability of preventive innovations. Since 2017, this collaboration funded a dedicated non-lethal specialist (based at WS) to identify non-lethal preventative options at the farm scale. The partnership has built the capacity of landholders to install, maintain and monitor preventive innovations such as turbo fladry and electric fencing. The Director of Montana WS, John Steuber, noted that there were no depredations on livestock inside 28 turbo fladry projects nor within the 67 electric fencing enclosures in areas that previously had a history of wolf depredation (Steuber, *pers. comm*). The collaboration has spurred the creation of two additional non-lethal-specialist positions to reduce negative interactions with large carnivores: a 'range rider' based in Montana and a specialist on preventive innovations in southwestern Oregon. Capacity building partnerships such as this are effective because they develop social capital (networks and working relationships) among different and often polarised stakeholders. Social capital is developed through dialogue creation and the social learning and trust that come from enhanced working relationships (Pretty and Ward 2001). Partnerships and collaborations require long-term funding and support from new and flexible governance systems that are effective, equitable, responsive and robust (Head et al. 2008; Carter and Linnell 2016; Bennett and Satterfield 2018).

Many root causes of negative interactions occur due to underlying conflicts between humans, such as between different cultural or ethnic backgrounds, stakeholder groups or between institutions and local people (Madden and McQuinn 2014). Conflict mediation and reduction engage interested or affected stakeholders in dialogue and help to bridge gaps between opposing views and values by attempting to find areas of commonality (Treves and Karanth 2003; Madden and McQuinn 2014). For example, the Montana partnership created multiple benefits because it *"makes people work together, on a common goal and brings people together, which is a benefit in itself. Sitting down and talking things out rather than fighting. Agreeing on things that we can agree on and learning that we're not that different and we could work together"* (Steuber, *pers. comm.*). This partnership shows that reducing the loss of livestock to carnivores and reducing the loss of carnivores are ultimately shared goals which can be achieved through the creation of an enabling environment to benefit all stakeholders (Young et al. 2018). Conflict engagement processes whether initiated by government, NGOs or from within the local community are most effective when they tap into local producer knowledge to understand the cause of the negative interaction and identify solutions to achieve shared goals (Wilson et al. 2005; Knapp and Fernandez-Gimenez 2009; Young et al. 2015, 2019). The willingness of government wildlife agents, animal protection and conservation practitioners to listen to affected groups is an important step towards reducing human to human conflict about carnivores (Zimmermann et al. 2010). As evidenced by parts of Montana, USA, barriers to adoption faced by individual producers (such as cost, social stigma, lack of capacity and experience) can be overcome in an enabling environment that assists the adoption of preventive innovations at a landscape level.

The personal sphere: Coexistence as a way of life

The influence of the personal sphere is often overlooked in facilitating a transition towards human–carnivore coexistence in rangeland systems. Observing the local environment, deep reflection and evaluating worldviews (i.e. values and beliefs) are necessary steps towards a shift in consciousness. This shift acknowledges sentient non-human beings and considers why one ought to extend the circle of compassion towards other beings, both human and non-human (Ives et al. 2020). Reflection may consider moving away from the one-sided categorical emphasis on negative interactions, and towards holistically considering the full spectrum of human–livestock–carnivore interactions. In this context, it may mean observing carnivores and their predator–prey interactions in the landscape and gaining a deeper insight into carnivore hunting behaviour, reflecting on their role in the environment and considering how this may influence livestock vulnerability and choice of risk reduction strategies.

Individually each leverage point is limited in its effectiveness to create change in the system. Activating leverage points across the three spheres (political, practical and personal) leads to mutually reinforcing transitions towards change. While the careful implementation of preventive innovations can reduce the tangible and intangible costs of living alongside carnivores. An enabling environment provides social support, funding, and builds capacity (skills, knowledge and confidence) to use preventive tools and practices (Madden and McQuinn 2014; McManus et al. 2015b). Deep reflection on the value of the current lethal carnivore persecution paradigm and consciously working with rather than against nature has the power to transcend the current paradigm (Meadows 1999). In this way, agriculture can facilitate a transition from reactive or retaliatory thinking towards a proactive paradigm that values coexistence at its core.

CONCLUSIONS

As large carnivore populations decline, there are increasing calls worldwide to prioritise their conservation (Ripple et al. 2014; Ferrier et al. 2019). Large carnivores are sensitive to human persecution so efforts to conserve large carnivores outside of protected areas, such as in rangelands, depends upon human tolerance for their existence (Bruskotter and Wilson 2014) and active conservation efforts such as the Montana partnership (Young et al. 2019). We outlined four reasons to transform relationships with large carnivores: the dominance of livestock production as a land use; large carnivores critical contributions to ecological functions; the high ethical, reputational, and social costs of large carnivores persecution; and the limited effectiveness of lethal control. Approaches that attempt to balance conservation and production objectives will require a conscious shift in worldviews as well as novel, bold, and deliberate actions (Fischer et al. 2006; Nicholson et al. 2009; Ripple et al. 2014). A new paradigm in human–livestock–carnivore coexistence must consider the spectrum of positive and negative interactions with large carnivores in the landscape. This can be achieved by engaging producers as key actors in SES and creating working relationships and safe spaces to discuss and explore options that aim to achieve multiple values in rangelands (Treves et al. 2016; Stone et al. 2017; Wallach et al. 2018). We proposed two key leverage points: the adoption of non-lethal preventive innovations and the creation of an enabling environment for adoption. These leverage points can facilitate a transition from the ancient and ongoing persecution of large carnivores towards tolerance and coexistence in rangelands and other multi-use landscapes.

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Chapter 5: Pathways towards coexistence with large carnivores in production systems

In chapter 5 I articulate the essential pathways to coexistence in the rangelands of South Africa and the US presented as models of transformation in extensive grazing systems. This research was published in the peer-reviewed journal Agriculture and Human Values in June 2021.

The success of human-carnivore coexistence relies on identifying pathways that are mutually beneficial for both humans and wildlife (Waudby et al. 2020). These pathways attend to the wellbeing of local communities that live alongside wildlife while also ensuring the just treatment of wildlife (Marchini et al. 2019). Holistically, these pathways if implemented, form an enabling environment to mainstream the adoption of preventive innovations. Deliberate system transformation Moore et al. (2014) to achieve coexistence requires progress along all pathways because they reinforce each other and create momentum for change.

Figures 1, 2 and 3 in the paper are shown the list of figures as below:

Figure 7: shown as figure 1: A conceptual model of transformation for extensive rangelands grazing.
Figure 8: shown as figure 2: A model of transformative change in extensive grazing systems in South Africa.

Figure 9: shown as figure 3: A model of transformative change in extensive grazing systems in western United States of America.

Pathways towards coexistence with large carnivores in production systems

L. Boronyak[1,5] · B. Jacobs[1] · A. Wallach[2] · J. McManus[3,4] · S. Stone[5] · S. Stevenson[6] · B. Smuts[3,4] · H. Zaranek[7]

Abstract

Coexistence between livestock grazing and carnivores in rangelands is a major challenge in terms of sustainable agriculture, animal welfare, species conservation and ecosystem function. Many effective non-lethal tools exist to protect livestock from predation, yet their adoption remains limited. Using a social-ecological transformations framework, we present two qualitative models that depict transformative change in rangelands grazing. Developed through participatory processes with stakeholders from South Africa and the United States of America, the models articulate drivers of change and the essential pathways to transition from routine lethal management of carnivores towards mutually beneficial coexistence. The pathways define broad actions that incorporate multiple values in grazing systems including changes to livestock management practices, financial support, industry capacity building, research, improved governance and marketing initiatives. A key finding is the new concept of 'Predator Smart Farming', a holistic and conscientious approach to agriculture, which increases the resilience of landscapes, animals (domesticated and wild) and rural livelihoods. Implementation of these multiple pathways would lead to a future system that ensures thriving agricultural communities, secure livelihoods, reduced violence toward animals, and landscapes that are productive and support species conservation and coexistence.

Keywords Sustainable agriculture · Animal welfare · Human-wildlife coexistence · Extensive grazing · Social-Ecological Systems

✉ L. Boronyak
Louise.Boronyak@uts.edu.au

B. Jacobs
Brent.Jacobs@uts.edu.au

A. Wallach
Arian.Wallach@uts.edu.au

1   Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia

2   Centre for Compassionate Conservation, University of Technology Sydney, Sydney, Australia

3   The Landmark Foundation, Western Cape, South Africa

4   Department of Biodiversity and Conservation Biology, University of the Western Cape, Cape Town, South Africa

5   International Wildlife Coexistence Network, Boise, Idaho, USA

6   Garden City, Idaho, USA

7   Tom Miner Basin, Helena, Montana, USA

Introduction

Human intolerance and persecution of large carnivores in production landscapes has deep historical and cultural roots (Woodroffe and Ginsberg 1998; Graham et al. 2005). Carnivore persecution not only presents a threat to lives of sentient beings, it also has been identified as a major constraint to conservation (Treves and Bruskotter 2014), to multi-species justice (Santiago-Ávila and Lynn 2020) and ecosystem health and function (Ripple et al. 2014). Carnivores are routinely killed to reduce predation on commercialised domestic animals in production systems such as sheep and cattle (hence 'livestock') (Ogada et al. 2003). However, evidence shows that killing carnivores often exacerbates livestock predation risk (see Berger 2006; McManus et al. 2015; Treves et al. 2016; Stone et al. 2017; Wallach et al. 2017; van Eeden et al. 2018a, b). Carnivore persecution is a key conservation concern as 77% of the world's largest carnivores are declining and 61% are threatened (Ripple et al. 2014). It has caused a contraction in large carnivore populations across their historical ranges (Ogada et al. 2003; Bergstrom 2017;

Stone et al. 2017), and subsequent loss of predation as an ecosystem service (Beschta and Ripple 2009). Carnivore persecution may also disrupt other ecosystem services that underpin agricultural production, such as primary productivity, nutrient cycling, soil richness, and pollination (Fischer et al. 2006; Naidoo et al. 2008; Beschta and Ripple 2009; Estes et al. 2011; Cardinale et al. 2012). Indeed, advances in conservation have demonstrated the importance of large carnivores in the maintenance of ecosystem health and function (Ripple et al. 2014).

Given the threats presented by persecution, there are increasing calls for acceptance and tolerance of carnivores in production landscapes (Manfredo et al. 2009; Treves and Bruskotter 2014; Johnson and Wallach 2016; Stone et al. 2017). These recommendations are part of wider calls for adopting models of sustainability across all human activities (Gunderson and Holling 2002; Folke et al. 2005; Abson et al. 2017; Sellberg et al. 2017). Wildlife friendly farming has been advocated as a model of sustainable farming that better balances agricultural and conservation interests (Green et al. 2005; Fischer et al. 2008; White 2012; Johnson and Wallach 2016). It values the use of preventive non-lethal innovations, which include various proactive and preventive practices and tools that aim to reduce the vulnerability of livestock to predation by minimizing encounters between livestock and carnivores (Stone et al. 2017; Boronyak et al. 2020). Wildlife friendly farming is a global farming movement in which wildlife are tolerated and protected in production landscapes (Johnson and Wallach 2016). Tolerance of wildlife involves an acceptance of the real and perceived costs and benefits of living alongside them (Bruskotter and Fulton 2012; Kansky et al. 2016).

Coexistence with carnivores requires fundamental system transformation because the current system prioritizes agricultural-financial interests over biodiversity conservation and is entrenched in lethal methods that significantly impact the persistence and welfare of carnivores (Bergstrom et al. 2014). Transformation represents fundamental changes across multiple systems: socio-cultural, political, economic and technological, resulting in the creation of a 'new system' (Van Den Bergh et al. 2011; Rickards and Howden 2012; Patterson et al. 2015). Transformations towards sustainability entail planned transitions and have been considered across a diverse range of issues including energy (van Vuuren et al. 2012), water (Pahl-Wostl 2002), agriculture (Rickards and Howden 2012; Gosnell et al. 2019) and cross cutting issues such as climate change (Abson et al. 2017; O'Brien 2018).

To explore pathways toward transformation in rangeland grazing systems we draw on Sellberg et al.'s (2017) integrative framework. This framework enhances a place-based understanding of ecological resilience and complex systems while also articulating various pathways that foster transformations towards global sustainability (Sellberg et al. 2017). Sellberg's framework integrates concepts of social-ecological resilience (maintenance of critical ecosystem services and avoidance of ecosystem degradation or collapse) (The Resilience Alliance 2010) with socio-technical transition theory that describes niche innovations and their interactions with existing social-technical regimes (Geels and Schot 2007). A social-ecological systems (SES) approach is useful in understanding the interplay of social, environmental and economic factors that drive human-wildlife conflict (Waudby et al. 2020). This approach also identifies interventions to move beyond maintaining business-as-usual practices towards the local–regional scale transformations, which this paper focuses on as human-carnivore coexistence. Coexistence has an explicit spatial–temporal–ecological dimension that implies species living together in the same landscape at the same time (Marchini et al. 2019). Yet it also has a relational dimension as it encompasses how people relate to and live alongside wildlife in ways that are peaceful and mutually beneficial (Marchini et al. 2019).

We present the results from a series of participatory engagement processes with key stakeholders to develop models of transformative change for rangeland grazing in South Africa and the United States (USA). We focused on commercial livestock production in South Africa and the USA to provide related but distinct case studies on the challenge of coexistence between humans and large carnivores in social-ecological systems, such as rangelands. We chose these countries because they encompass large areas broadly defined as rangelands (United States: 31% of 11 states land areas; South Africa: 91% of the land area) that are used extensively for livestock grazing (Havstad et al. 2007; Goldblatt 2011; Palmer and Bennett 2013); and are inhabited by diverse array of large carnivores (Carnivora species with body mass > 10 kg; hence carnivores); and have a long history of carnivore persecution livestock producers (hence producers). Large carnivores such as leopard (*Panthera pardus*) are still prevalent in South Africa's rangelands (Swanepoel et al. 2013). In the USA, coyotes are common rangeland predators, and increasingly wolf (*C. lupus*), bear (*Ursus* spp.), and cougar (*Puma concolor*) as populations are recovering in rangelands (Schwartz et al. 2001; Kendall et al. 2009; Maletzke et al. 2016; Gigliotti et al. 2019).

The models developed in this study describe four key components (Jacobs et al. 2017): (1) the current dominant functioning of the system (business-as-usual); (2) the drivers of change that exert pressure on business-as-usual and determine the extent and direction of change within the system; (3) the vision and characteristics of a 'desired' future (the 'transformed system') that incorporates multiple values, and (4) transition pathways as a continuous processes of change along a range of possible development paths that emerge from individual and collective actions, and which

deviate from what is considered the norm. These multiple pathways provide a bridge to the transformed system and act to reinforce each other to create transformative change. Pathways approaches call for adaptive, context-specific actions to address sustainability challenges and also recognise that there are multiple alternatives or pathways towards socio-ecological sustainability (Cockburn et al. 2018) and therefore provide a solid frame to explore human-carnivore coexistence.

Methods

Norström et al. (2020) defined four principles for knowledge co-production within the field of sustainability research as being context-based, pluralistic, goal-orientated and interactive. We employed these co-production principles to gather the information needed to develop the change models. The research was situated in the context of rangeland grazing systems in two countries, it engaged interactively with multiple knowledge sources (e.g. academic and informal) from diverse stakeholders with the explicit goal of transforming current management practices in each country (Djenontin and Meadow 2018). For South Africa, the change model was developed through multiple engagements, initially in a workshop with livestock producers, conservationists, experts and practitioners at the *Pathways to Coexistence* Conference in Namibia in 2018. A model template (Fig. 1) was used to guide discussions and elicit information from 40 workshop

participants on the topic of human-carnivore conflicts in extensive rangelands grazing in Africa. The participants provided information that was used to populate the four components of the template (i.e. drivers of change, business-as-usual, transition pathways and the transformed system) and presented a model of transformative change (Jacobs et al. 2017). The models are not intended to depict mechanistic relationships between components because, for example, a single pathway is unlikely to directly connect single attributes of the current system state with those of the transformed system. The template is based on a modified 'three-horizons' approach used in futures work that connects the present with visioning divergent futures based on a set of values (Curry and Hodgson 2008). The timescale, determined through stakeholder deliberation at the workshop, starts when the stakeholders were first engaged in 2018 and ends with a future system in the year 2040 in recognition of the likely extended timescales required to realistically achieve transformation in an SES.

Information from the workshop was supplemented, verified and refined for the South African context through semi-structured interviews with 16 livestock producers, two conservation non-government organizations (NGOs), and two government representatives (20 individuals in total). The interviews occurred in three provinces in South Africa including the Eastern and Western Cape and the Free State. We used a purposive sampling procedure (Bryant and Charmaz 2010) to identify key stakeholders that possessed specialist knowledge in livestock production,
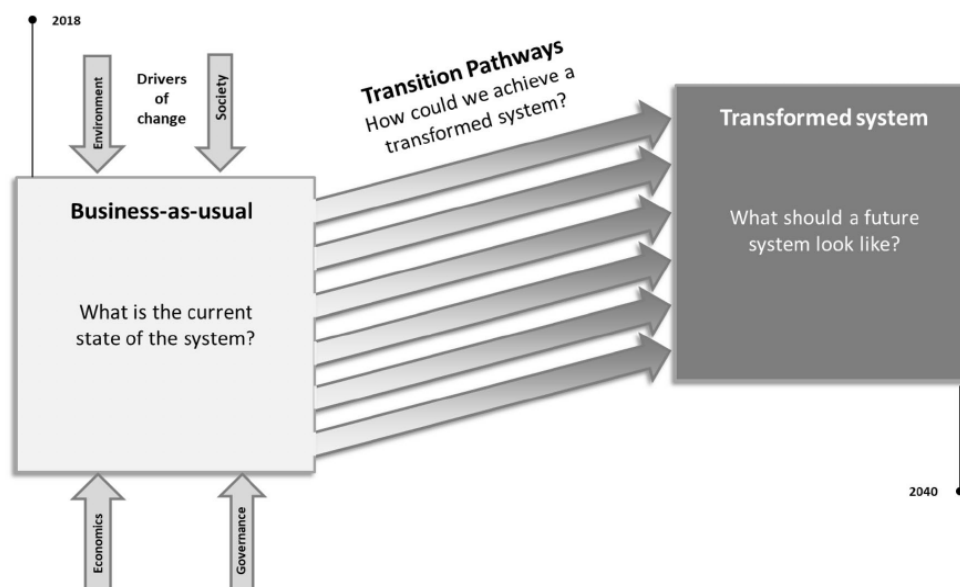
Fig. 1 A conceptual model of transformation for extensive grazing of rangeland systems (Adapted from Jacobs et al. 2016)

human-carnivore interactions in rangelands grazing and the capacity to mitigate predation risk in livestock grazing. Initially, stakeholders were recruited via existing contacts with environmental NGOs in South Africa and the USA. At the conclusion of each interview, we asked each interviewee to recommend additional producers. This snowball sampling method increased the sample size, broadened the extent of viewpoints canvased (to include users of lethal and non-lethal carnivore management practices) and ensured theoretical saturation or the point in data collection and analysis when new incoming data produces little or no new information to address the research questions (Glasser and Strauss 2009). In the USA in total 16 commercial producers were interviewed with 12 relying primarily on non-lethal tools and approaches (herein non-lethal producers) and four relying on lethal approaches to manage predation risk (herein lethal producers). Similarly, in South Africa 16 commercial producers were interviewed, with the sample comprising nine non-lethal producers and seven that used lethal management practices. The semi-structured interviews were conducted in person and averaged between 60–90 min. All of the stakeholders that participated in a workshop or interview were provided with an information sheet outlining the scope of the research and provided informed consent to participate in the research. Human research ethics approval was granted by the University of Technology Sydney (ETH18-2568—HREC). During analysis qualitative data were synthesised and anonymised.

The interviews commenced with participants introducing themselves and giving an overview of their livestock operation or role in government or NGO and their interactions with carnivores. Specifically, producers were asked about the impacts of predation on their business, and all stakeholders were asked about their preferred approaches to mitigating predation (i.e., lethal or non-lethal to carnivores), their perceived effectiveness of each mitigation approach, landscape management, and the available supports and incentives to adopt preventive non-lethal innovations (herein preventive innovations) (e.g. Pannell and Vanclay 2011; Boronyak et al. 2020). Interviews concluded with participants' envisioning the possible or preferred future in the year 2040.

The model for rangelands grazing in the western USA was developed from information gathered during semi-structured interviews conducted between 2018 and 2019 with representatives from California, Idaho, Oregon, and Montana. The same participant recruitment and interview process was followed in South Africa. Interviews were conducted with 16 livestock producers, six former and current representatives from government wildlife agencies, and 3 conservation NGOs (25 individuals in total). Information from the interviews was supplemented with lessons from the Defenders of Wildlife Coexistence conference October 2019. With the participants' consent, all interviews in both countries

were audio recorded, transcribed verbatim and analyzed using MAXQDA software (VERBI GmbH version 18.2.0). The transcripts were coded line-by-line (Saldana 2009) into categories that corresponded to the four components of the model. The information was collated, synthesized and then transferred to the model template.

As the USA model was collated from information gathered by interviews only, it was validated using a modified Delphi approach. The Delphi approach seeks to ensure accuracy, reach a consensus, and check for omissions or misinterpretation but not alter content provided in the original engagement process (Mead and Moseley 2001) by drawing on diverse knowledge and experiences of a range of experts (Powell 2002). The draft model was sent to 10 of the interviewees representing a mix of livestock production, conservation and governance to elicit feedback. Feedback was received through three rounds of comments from seven participants in total: five participants in rounds one and two, and two participants in round three. At each round, the model was revised, comments anonymized and returned to the original ten participants. The model was finalized when consensus was achieved among the experts.

Results

The South African model

The information gathered through engagement with stakeholders was synthesised into a model of transformative change in South African extensive grazing systems (Fig. 2).

System drivers

Participants discussed a range of drivers of change that act on extensive rangelands grazing systems in South Africa. Representatives from environmental NGOs recognized South Africa's rich biological diversity, however land use change and overgrazing due to agriculture, as well as the impacts from mining and urbanisation were viewed as contributing to the loss and degradation of natural habitat, soils and biodiversity. In South Africa, 69% of the land surface is suited to livestock grazing yet grasslands are one of the country's most threatened biomes (Goldblatt 2011) due to growing pressure to maximize productivity to feed a growing human population. Similarly, wildlife faces pressure from both consumptive use, such as hunting on private game farms, and non-consumptive use through eco-tourism activities on private game reserves, national parks and other protected areas. Workshop participants noted that local community values and perceptions of carnivores influence their treatment. For example, leopards appear to have a high perceived value (i.e., high aesthetic, conservation or tourism
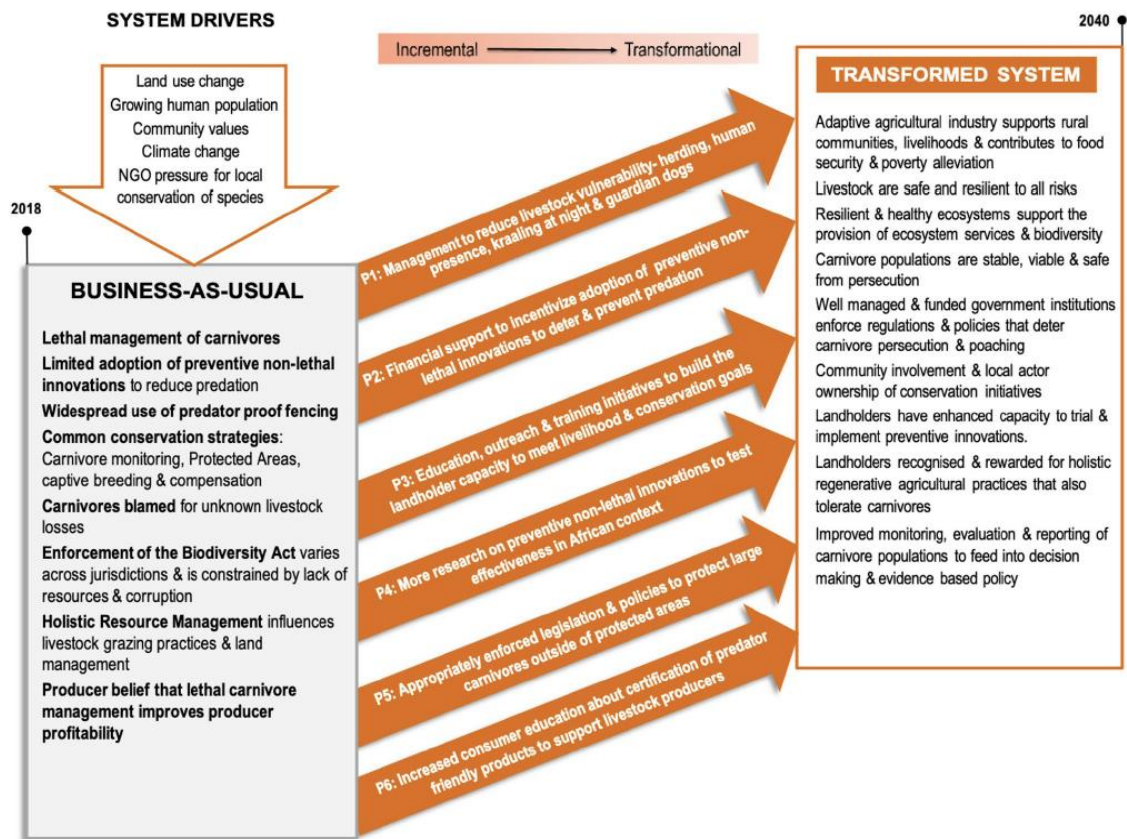
Fig. 2 A model of transformative change in extensive grazing systems in South Africa. Pathways are numbered P1 to P6

value) and were tolerated more other carnivores such as a black-backed jackal yet it remains unclear how any financial benefits from leopards are shared with local communities. Lastly, the impacts of climate change in the form of changing rainfall patterns and extended drought are exacerbating groundcover loss, particularly in grazed arid rangelands, affecting long-term soil health and water retention. Loss of forage was identified as affecting the nutrition and health of domesticated livestock making them more vulnerable to predation, which can heighten on-going human-carnivore conflict.

The producers who predominantly used lethal control appeared to have negative attitudes towards carnivores, predominantly black-backed jackals and caracal. They perceived these species as 'vermin' to be eradicated. These views were driving the increasing militarisation of carnivore control with the use of night vision glasses, devices that mimicked the vocalisations of carnivores (referred to as night callers), modification of vehicle seating to facilitate use of firearms,

as well as community organised and funded ground and aerial shooting from a helicopter. This has culminated in a high degree of social pressure to continue to persecute carnivores, the cost of which is borne by individual landholders. In seeking to counter the trend of ecosystem degradation and carnivore persecution, local and international NGOs are pushing to protect carnivores outside protected areas and demonstrate that holistic models of coexistence that preserve natural resources (soils, habitat and biodiversity) can be economically viable.

Current system

Business-as-usual in South African extensive grazing systems was characterized by the continued persecution of leopard, caracal, and black-backed jackal. Producers reported that carnivore persecution on individual farms was undertaken by staff or private contractors using shooting, trapping and hunting with dogs. Some lethal producers reported using

poisons (e.g., Temik and Sodium fluoroacetate) despite the un-licensed use of poison against wildlife being legally prohibited in South Africa.

The use of preventive non-lethal innovations appeared to be ad hoc and limited, with the most widely reported strategy used by producers being permanent predator-proof or temporary electric fencing. Workshop participants that identified themselves as conservation researchers noted that permanent fencing impedes the movement of wildlife and poses a danger of entanglement. Non-lethal producers reported success using guardian animals (i.e., livestock guardian dogs and alpacas) and guardian humans to reduce theft and predation. Producers recognized that livestock herding and guarding by humans is effective at reducing predation yet had reservations about the cost of hiring and managing extra staff. Producers instead installed electric fencing despite its high cost and limitations from shorting-out from vegetation or damage from wildlife. Some producers had adopted preventive innovations (e.g., deterrents such as flashing lights or sounds or livestock protection collars to prevent carnivores biting livestock around the neck). Several producers mentioned the influence of 'holistic resource management' and its variants on their grazing practices. Holistic resource management involves high-density short-duration grazing followed by an extended rest period for the land with no grazing. Producers using holistic resource management noted various landscape benefits such as mechanical soil disturbance and nutrient cycling allowing for greater water infiltration and improved plant growth and diversity after rainfall compared with lower density set-stocking.

At the institutional level, human-carnivore conflicts were reportedly managed through the use of 'destruction permits' issued by parastatal or governmental agencies. Responsibilities varied across provinces e.g., Cape Nature in the Western Cape and the Department of Economic Development and Environmental Affairs in the Eastern Cape. Workshop participants identified a range of carnivore conservation strategies including population monitoring, conservation in protected areas (e.g., national parks and private conservancies), captive breeding and translocations. Government departments tasked with administering legislation to protect carnivores e.g., *Biodiversity Act 2004*, Threatened or Protected Species Regulations (TOPS), and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), were viewed as being limited by insufficient resources and funding resulting in varied degrees of enforcement across provinces.

Pathways

Information from participants was synthesised into six discrete transition pathways to activate change in the system (P1 to P6 from top to bottom of the model). P1 is focused on the individual farm or property level and includes adoption of a range of preventive innovations to reduce predation. Four non-lethal producers reported using livestock guarding animals such as dogs and alpacas; the Anatolian and the Africanis Maluti breeds of livestock guarding dogs were reported as the most common breeds. A further four producers preferred aversive deterrents such as flashing lights and sounds especially during vulnerable periods, such as lambing and calving, as well as mixing livestock types (cows with calves and sheep) and kraaling (corralling) at night. However, producers noted the need to frequently change stimuli to reduce carnivore habituation, for example moving the location of the lights or varying the types of sounds. Other practices drew on the principles of holistic resource management to modify grazing styles. For example, livestock were concentrated into a dense herd, primarily to improve herbage growth and soil health, with the co-benefits of reduced livestock predation and parasite infestation. Producers attributed reduced predation to mimicry in denser herds of successful predator avoidance strategies used by wild ungulates. Greater human presence may also deter carnivores due to sounds and scents associated with human activity. More intense livestock management encourages daily inspections of herd health and interventions to reduce livestock vulnerability such as removing sick or injured livestock from the landscape that also provides local employment opportunities and poverty alleviation in rural areas. One non-lethal producer noted that the practice of kraaling livestock at night also decreases the area that needs to be patrolled by guard humans or animals and increases the efficacy of aversive deterrents such as flashing lights.

The second pathway (P2) creates financial incentives, funded by local or international conservation NGOs or government agencies to assist producers to adopt preventive innovations identified in P1. P3 centres on education, capacity building and outreach to build the skills of system actors to utilise preventive innovations such as livestock guardian animals (from P1) that might require training to be effective in the landscape. Producers noted that on-farm demonstrations and field days provided a practical way to learn about P1 tools and practices and exchange ideas. This pathway encompasses knowledge to enhance ecological literacy relating to carnivores within the grazing industry such as their lifecycles, hunting styles, annual patterns of activity, natural prey, and strategies to build producer tolerance towards carnivores. P4 provides a role for conservation specialists, universities and agricultural representatives to collaborate with landholders in decision-making, research and development. These collaborations would test and refine non-lethal tools or practices that work best under the range of production systems, livestock breeds, landscape conditions, and the common carnivores, their associated hunting traits, and sensitivity to the range of available aversive deterrents.

P5 encourages governance from national to provincial levels to improve policy and appropriately enforce legislation for the protection of large carnivores outside protected areas. The aim of P5 is to better balance the needs of people and wildlife through monitoring and deterrence of illegal poaching. Finally, P6 seeks to harness the power of consumers to make ethical choices in relation to sourcing meat and fibre from producers who adopt preventive innovations. Progress along this pathway could be achieved through branding or labelling that certifies ecosystem-appropriate stewardship and non-lethal approaches to managing predation risk. For example, Fair Game established by the Landmark Foundation provides a premium to producers who refrain from lethal carnivore control and on-sells livestock products to consumers, retailers and restaurants (https://www.landmarkfoundation.org.za/fair-game). At the time of the study, producers considered this market 'niche' in South Africa and felt there would be more demand in European markets. Similarly, workshop participants in particular identified the need to stimulate awareness for predator friendly certified products and demand via targeted media campaigns. The intention of this pathway is to provide a financial incentive to improve ecological stewardship by retaining carnivores in the landscape through demand created by new markets.

Transformed system

Conservationists and producers described different but complementary aspects of a future transformed system. Livestock producers envisioned an agricultural industry that is adaptive, supports rural communities and livelihoods, and contributes to local and global food security. Livestock are protected from harm associated with stress, injury or death through reduced exposure to predation risks. This is underpinned by an enabling environment in which support networks provide incentives and build capacity for producers to learn about and adopt contextually appropriate preventive non-lethal innovations and holistic regenerative agricultural practices. A fundamental component of such support networks is the provision of financial support for landholders to offset the costs of adopting practices such herders, guardian animals and regenerative agriculture. The expansion of sustainability certification to include a predator-friendly marketing scheme would allow participating producers to reach new market segments in South Africa and internationally and reward producers who are ecologically focused.

Conservationists envisioned a desirable future grazing system in which populations of carnivores are stable and viable. Ecosystems are "resilient" and "healthy" and provide "valuable ecosystem services". Secure long-term funding enables the creation of governance structures for greater enforcement of regulations, and policies that effectively deter carnivore persecution as well as long-term monitoring

of carnivore populations to aid decision making. These arrangements are underpinned by well-managed, resourced, and transparent government institutions that support conflict avoidance research and development, and coexistence. Furthermore, local communities and actors in conservation initiatives are essential for wildlife conservation and therefore fundamental to the transformed system. Local communities can be challenged by living alongside carnivores but can also share in the benefits of incomes derived from sustainable, low impact wildlife eco-tourism. The combination of the pathways would likely mainstream the adoption of predator-friendly farming practices and increase the health and resilience of livestock, land and livelihoods. Overall, the model illustrates how coexistence can be achieved in rangeland landscapes in South Africa.

The United States of America model

A similar change model was developed for rangeland grazing systems of the western USA (Fig. 3).

System drivers

Participating conservationists and producers (ranchers) identified the recovery of large carnivores as one of the most obvious changes occurring in extensive grazing systems in western USA. While species recovery may be counted as a success, other key stakeholders, particularly producers and some government representatives, viewed this as a driver of conflict. Interviewees suggested that increasing urbanization is driving change in the perception of wildlife in communities with greater value placed on the opportunity to see large carnivores in the wild. At the same time demand is growing for food and fiber products that are ethical, healthy, environmentally sustainable, and incorporates practices that promote good animal welfare and environmental stewardship. This shift also contributes to an urban–rural divide over carnivore management with urban communities opposing lethal management that is more widely supported by rural communities.

Current system

Business-as-usual in western grazing was viewed by participants as undergoing change. As populations of large carnivores begin to recover (i.e., no longer classified as endangered) their management is transferred from the Federal jurisdiction, under the U.S. Fish and Wildlife Service, to state agencies. State policies and the species' population status were perceived as factors influencing the perception and treatment of carnivores. For example, the Idaho Department of Fish and Game awarded The Foundation for Wildlife Management grants of $20,000 in 2018 and $13,220
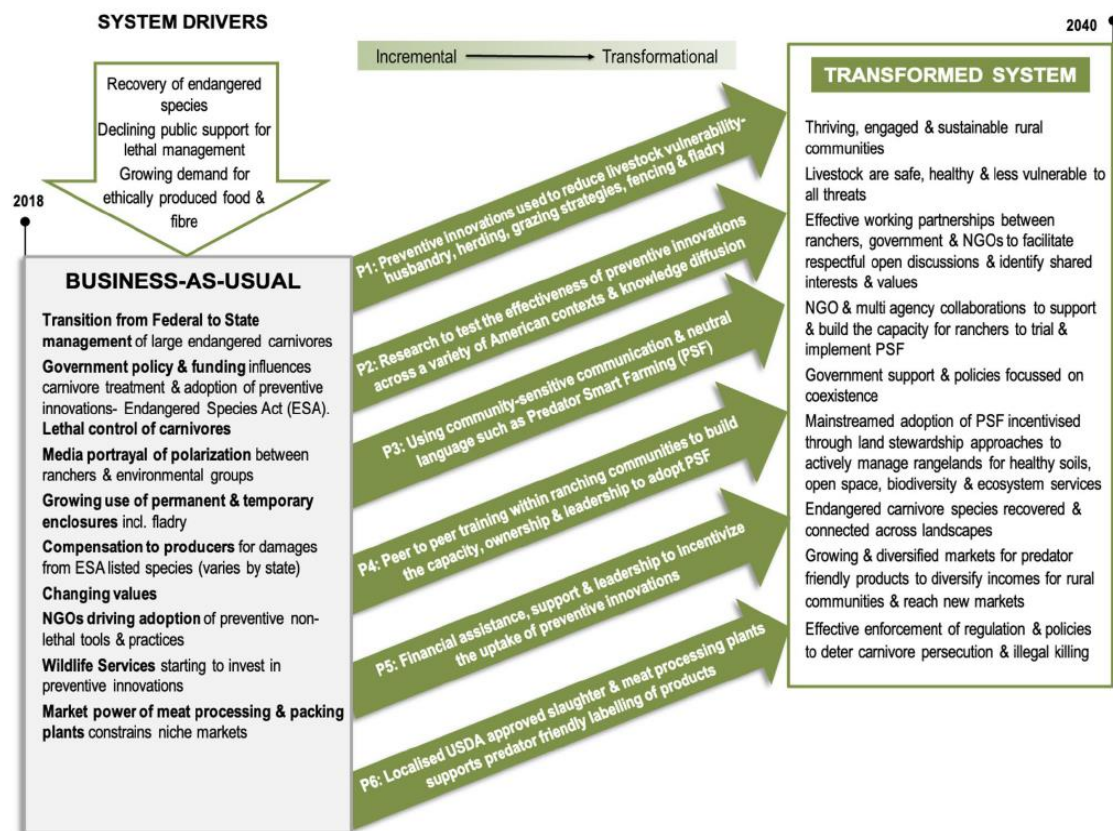
Fig. 3 A model of transformative change in extensive grazing systems in western United States of America. Pathways are numbered P1 to P6

in 2020 to reimburse hunters and trappers for expenses incurred while killing wolves. These grants effectively provide a bounty to kill wolves in Idaho (IDFG 2018, 2020). Environmental and wildlife protection NGOs argued that the liberal use of lethal control results in environmental, social and animal welfare harms. However, hunting groups argue that carnivores reduce populations of valued game species such as deer and elk. A combination of these factors has caused social conflicts between seemingly opposing groups such as ranchers and environmental advocates.

Interviewees from conservation NGOs spoke of changing community values in terms of growing public awareness and appreciation of the value of wildlife, such as wildlife viewing, supporting environmental protection, and declining support for lethal carnivore management and trophy hunting. However, two policy makers noted that support for hunting remains strong in rural communities. The shift towards non-lethal management has been facilitated by conservation groups pressuring government agencies to change the laws and funding allocations for wildlife management. For example, Wildlife Services is investing in preventive non-lethal innovations with $1.38 M of US Federal funding allocated for wildlife conflict-prevention specialists across ten states (https://tinyurl.com/y42hzsjo). This initiative is supported by increasing evidence of the efficacy of preventive innovations over lethal control at the local scale. As consumers' awareness rises in relation to lethal control of wildlife for livestock protection so too does support for Predator Friendly certified products. However, producers noted the challenges in participating in these kinds of labelling programs due to market power of meat processing and packing plants, with producers lacking control over how products are labeled once they sell into that system, and their ability to ensure supply to these markets.

Pathways

As with the South African model, information from participants was synthesized into six discrete transition pathways to realize a transformation in rangelands grazing. P1 centres on the adoption within ranching communities of preventive innovations (both tools and practices) to reduce the vulnerability of livestock to predation and carnivores to persecution (Fig. 3). Interviewees identified a range of actions including:

- Guarding livestock (herders, range riders and guardian animals),
- Husbandry practices that reduce encounter rates between predators and livestock (e.g., range riding, tighter herding of livestock especially at night using night pens, reducing isolation of young calves and lambs from their mothers, and avoidance of heavily forested areas, riparian areas or sites of known carnivore activity),
- Optimising herd health (e.g., sound vaccination, handling and nutrition protocols),
- Removing attractants such as livestock carcasses and bone yards,
- Planned grazing strategies (e.g., more intensive yet short term grazing, use of permanent and temporary enclosures or installation of additional watering points).

P2 focusses on research to test the effectiveness of preventive non-lethal innovations in a range of production contexts and variety of carnivorous species. This research provides insights into carnivore behavior, the underlying factors driving conflicts, the location of conflict hotspots and refinement of the protocols for the use of existing preventive innovations (e.g., deployment of fladry or use of livestock guardian animals) considered to be the most effective practices by non-lethal ranchers and environmental NGOs.

P3 recognizes that clear and effective communication is essential to achieving long-term successful carnivore conservation in multi-use landscapes. The concept of Predator Smart Farming (PSF) emerged from the stakeholder interviews as the producers' preferred term. PSF was not only more palatable for ranchers than the terms 'wildlife-' or 'predator-friendly' but also had greater alignment with ranching communities' values. The word 'smart' appealed to producers who were keen to use innovative tools and practices to 'outsmart' carnivores. PSF was described as a holistic and conscientious approach to agriculture to increase the resilience of landscapes, animals (domesticated and wild) and rural livelihoods, encompassing three key aspects. Firstly, it focuses on reducing the vulnerability of livestock to risks, including disease, environment (e.g., poisonous plants), climate (e.g., drought) and predation. Secondly, it has a social–ecological stewardship mindset, identified as common among practitioners of 'regenerative

agriculture' (Gibbons 2020), that fosters ethical and responsible interactions within production landscapes to maintain the underlying ecosystem and landscape processes. Thirdly, PSF fosters financially resilient livelihoods that reduce the costs and capitalise on the benefits of large carnivores in the landscape (e.g. reduced grazing pressure and/or spread of disease e.g. brucellosis from wild herbivores). The expanded framing of grazing practice, shifts the emphasis from carnivore control to land and livestock management, would create the space to initiate and hold more productive conversations about large carnivore conservation.

The adoption of PSF is reinforced by P4 that recognises that peer to peer education (i.e., producer to producer), knowledge exchange and training within ranching communities is an effective way to overcome the socio-cultural resistance towards new tools and practices. P4 builds capacity (skills, knowledge and confidence) and ownership of PSF at the grassroots level supported by an enabling environment that fosters effective working partnerships between ranchers, government and NGOs. Examples include the Tom Miner Basin Association (http://tomminerbasinassociation.org/) and the Blackfoot Challenge (https://blackfootchallenge.org/). Capacity building efforts would be assisted by P5 that works to, firstly, develop policy that encourages the use of preventive innovations as a first response to managing conflict. Secondly, P5 acts to expand the array of tools that can be utilized to reduce predation risk and reduce reliance on lethal control. For example, in eastern Oregon a rancher must show they are suffering ongoing loss from predation after implementing two preventive innovations such as fladry (suspended strips of fabric or coloured flags that move in a breeze) or aversive deterrents before a lethal control order can be issued (Oregon Department of Fish and Wildlife 2014). Thirdly, P5 includes financial incentives for adoption of preventive innovations, such as NGO programs that make a co-contribution to non-lethal deterrents in regions where large carnivores are still federally listed species, in addition to government grants to overcome the initial financial barrier to adoption. Such support to producers was perceived by conservation NGOs as a way to create an enabling environment, initiate conversations and start building trust with farming communities that may hold negative attitudes to carnivores, conservation organisations and government.

The final pathway, P6, focuses on increasing the number of local United States Department of Agriculture (USDA) approved slaughter and meat processing plants to support producers who want to run their own labelling schemes. P6 encourages growth in the market for PSF products, allows producers to reach new consumers and rewards producers who have a more holistic mindset. However, NGOs and some producers agreed that P6 requires increased demand for certified products. Creating markets for PSF products requires increased consumer education about

the ecological, animal welfare and socio-economic benefits of PSF products. Environmental NGO participants in the USA indicated that expanded PSF labelling schemes could counter-balance the high market power of feedlots and huge slaughtering houses in the Midwestern USA and would enable environmentally conscious labelling schemes to move from niche to more mainstream. More importantly product labelling is needed to recognize the efforts (learning, costs etc.) of transitioning from 'conventional' to alternative livestock production systems for long-term sustainability.

Transformed system

The vision of a desirable future includes rural communities that are thriving, engaged and ecologically sustainable supported by a diversified rural economy. Livestock are safe, healthy and less vulnerable to all threats encountered in extensive grazing, supported by an enabling environment that fosters effective working partnerships between ranchers, government and NGOs. Partnerships are based on respectful open discussions and collaboration that identifies shared interests and goals such as healthy ecosystems, agricultural viability and food security. This vision serves common interests, not special interests or entrenched positions. Ranchers, NGOs and agencies collaborate to build the capacity to research, trial and implement preventive innovations that are suited to local landscapes, economies and livestock operations. This collaboration is facilitated by government support, policies and regulations that fund research, promote dissemination of knowledge about large carnivores, effectively deter illegal killing and encourage human-carnivore coexistence.

Carnivore management forms part of the larger regenerative agriculture movement, which prioritises and incentivises approaches that actively manage rangelands for healthy soils, open space and greater biodiversity and ecosystem services. Our models incorporate transformed systems where once endangered large carnivores inhabit their historical range and contribute to ecosystem health and functioning supported by a sufficient natural prey base. Tolerance towards large carnivores is enhanced by the mainstreamed adoption of preventive innovations. NGOs and government help to over-come financial and capacity barriers such as the material costs, knowledge gaps, and necessary labour to implement PSF practices. Markets for a diverse range of predator-friendly agricultural products are growing and help sustain rural communities and incentivise a holistic eco-centric approach to land management.

Discussion

Through engagement with a range of key stakeholders, we developed two qualitative models of change that show transition from business-as-usual via various pathways to transform interactions between humans and large carnivores from conflict to coexistence in rangeland systems (Figs. 2 and 3). The engagement drew upon various sources of knowledge, highlights a range of views on human-carnivore coexistence and identifies multiple, mutually supporting pathways towards a transformed future. The current system, described in terms of system drivers and business-as-usual, in each country has evolved under local historical, political, socio-cultural, economic and biophysical contexts. Despite these variations in local context, there are many similarities in these rangeland grazing systems. In both South Africa and the USA, there is a reliance on lethal methods such as shooting and trapping to resolve human-carnivore conflicts (McManus et al. 2015; Treves et al. 2016). In both countries, carnivore persecution was justified by the desire to protect agricultural productivity and livelihoods. However, the differences between the countries primarily relates to the institutional context and level of support for producers for lethal carnivore control. For example, it appears that in the last four decades producers in the United States were provided with significantly more institutional support for lethal control than in South Africa. This institutional support heavily subsidised the cost of predator control for US producers. In contrast, agricultural policy in South Africa during the 1980s saw a withdrawal from subsidised lethal carnivore control including bounty payments, support for hunting with dogs and the provision of poisons (Nattrass et al. 2020). These subsidies were replaced with predator hunting services by private consultants or undertaken by producers themselves. A recent South African study (Brink et al. 2021) found that the use of poisons for lethal carnivore control is widespread. An estimated 31% of the farmers surveyed over 5-year period used poisons against carnivores because it was considered one of the least labour-intensive lethal control options (Brink et al. 2021). Although developed independently, as each change model deals with human-carnivore interactions in extensive grazing systems, it is unsurprising that there are similarities in pathways from each country.

At the heart of each model are the potential pathways that represent incremental changes (e.g., use of predator deterrents on an individual farm) that culminate in longer-term transformative change (i.e., coexistence). The initial actions from business-as-usual onto the transition pathways can be considered as critical low-risk steps that avoid the disruption to the system that might occur if ecological

thresholds were de-stabilized (Price and Hacker 2009). The key areas of overlap in the pathways include the various leverage or intervention points to encourage adoption of preventive innovations via incentives, capacity building and governance structures that balance human and carnivore needs. This aligns with the work of Chan et al. (2020) who identified levers and leverage points that are key to achieving transformations towards greater global sustainability. These levers include pre-emptive action (P1&4 in South African model and P1&2 in USA model), incentives and capacity building (P2,3&4 in South African model and P4&5 in USA model), coordination across different sectors and jurisdictions (P3&4 in South African model and P2,3&4 in USA model), adaptive decision-making and environmental law and its enforcement (P5 in South African model) (Chan et al. 2020). While progress along all pathways is important to achieve transformation, they operate at varying scales (from national to regional and local), and mutually reinforce each other to create 'sticky' change that over time becomes more acceptable and durable ensuring a lower likelihood of being reversed by a change in policy (Levin et al. 2012) or dis-adopted (Chinseu et al. 2019).

Governance is critical to any intentional effort to shape transformations towards sustainability (Patterson et al. 2015). Governance arrangements that encourage effective partnerships between producers, government and NGOs are vital to facilitate respectful open discussions that use neutral language and identify shared interests and values (Madden and McQuinn 2014; Chan et al. 2020). Therefore, new institutional arrangements that promote ecosystem governance in ways that are adaptable, flexible, and incorporate multiple stakeholder values are required to facilitate transitions away from business-as-usual (Walker and Salt 2006; Head and Alford 2015). For example, in USA, the Oregon Wolf Plan "emphasizes the importance and mandates the implementation of non-lethal efforts to reduce wolf-livestock conflict before lethal removal is considered in all phases of wolf management" (Oregon Department of Fish and Wildlife 2014, p. 10). These kinds of policies challenge the current regime (business-as-usual) and have the power to leverage transformation because they shift the system from its dominant mode of operation i.e., reliance on lethal carnivore control toward a future system that incorporates multiple values (production and wildlife conservation and welfare) and human-carnivore coexistence. This is an important consideration when planning for coexistence as it requires decision making that accounts for the interests of a variety of stakeholders (Marchini et al. 2019).

Another factor that is adding pressure to the current regime particularly in the USA relates to the shift in consciousness about the ethics of killing large numbers of wildlife to protect special interests (i.e. livestock production).

Research from the USA indicates that as the public has become increasingly urban and modernised, values have shifted away from domination over nature towards mutualism with nature (Manfredo et al. 2009), with the public increasingly attributing intrinsic value to wildlife. Furthermore, developments in both conservation and animal welfare sciences have demonstrated the importance of large carnivores in maintenance of the health and function of ecosystems (Ripple et al. 2014) and the negative welfare implications of the methods commonly used in lethal control (Littin and Mellor 2005). Within urban communities there has been a decline in public support for lethal methods and a shift in favor of finding solutions that can protect agriculture and carnivores simultaneously (Graham et al. 2005; Slagle et al. 2013; Manfredo et al. 2018). This has created a greater impetus for conservation NGOs as agitators of change to pressure livestock industries to transition away from traditional lethal approaches towards the adoption preventive innovations that support wildlife persistence (Young et al. 2019).

When producers feel their livelihoods and way of life are under threat, this can contribute to polarisation between groups who hold different values and social norms. Therefore during 'high stakes' conversations such as discussions about carnivore management, the use of neutral language is essential to building openness, trust and collaboration to explore shared goals. It is important to focus on mutual benefits and use language that de-escalates polarized schisms among stakeholders involved in rangeland management. A key finding from the USA model is the concept of PSF because it shifts the focus from carnivores towards three aspects: (1) livestock management and husbandry to reduce predation risk and carnivore persecution, (2) social–ecological stewardship to build the resilience and productive capacity of landscapes, and (3) security of rural livelihoods, all of which are of paramount importance to farming communities. The social–ecological stewardship mindset of PSF focusses on restoring resilient production landscapes that are capable of producing a full suite of ecosystem services including soil carbon sequestration, water retention and biodiversity (Gosnell et al. 2019; Schurch et al. 2021). Whereas, investigating ways to secure livelihoods focusses on reducing the costs and capitalising on the benefits of large carnivores in the landscape such as reduced grazing pressure from wild herbivores or diversifying incomes through eco-tourism and farm stays (Prowse et al. 2015). This expanded framing of grazing we believe would assist in initiating conversations about large carnivore conservation and builds positive working relationships between wildlife managers, government agencies, environmental and animal protection NGOs, livestock producers and local communities.

In both models pathways focus on the adoption of contextually appropriate preventive innovations by producers.

These include deterrents, temporary or permanent enclosures, guardian animals and husbandry protocols, because they are central to reducing livestock vulnerability and predation risk (Baker et al. 2008; van Eeden et al. 2018a, b). The benefits of deterrents and enclosures have been discussed extensively (Shivik et al. 2003; Stone et al. 2017; Young et al. 2019). Yet husbandry in general remains an under-utilized practice for the management of predation. Three non-lethal producers from the USA suggested that many preventive innovations are forms of active livestock management and the focus should switch from controlling carnivores to the core concern of maintaining livestock health and resilience. Active management includes human presence to observe for signs of disease, nutritional deficiencies or restlessness, and extra vigilance during high risk periods (i.e. lambing and calving) or when carnivores are most active (White 2012; Stone et al. 2017). Woodroffe and Frank (2005) reported similar findings about the value of livestock husbandry practices to reduce predation risk in rangelands in northern Kenya, Africa. In addition, Ogada et al. (2003) identified that predation rates were reduced when livestock were herded by day and enclosed in traditional corrals (bomas) at night, guarded by humans and dogs. In our study, participants from wildlife agencies and NGOs saw a key role here in assisting producers in adoption of active management through increasing their understanding of patterns in carnivore behaviour, that is, how and when carnivores move through certain parts of the landscapes, seasons when they are most active and how hunting behaviour influences livestock vulnerability (Baker et al. 2008). This knowledge informs risk reduction strategies, such as planned grazing to avoid areas that result in an ambush attack by a carnivore and/or concentrating livestock into a dense herd as a predator avoidance strategy (Bøving and Post 1997; Graham et al. 2005; Fryxell et al. 2007). Producers, particularly in South Africa, believed higher density herds offer various benefits by utilising a smaller part of the property for grazing, thus allowing longer rest periods to encourage plant growth and soil health (McManus et al. 2018). This grazing style requires increased human presence from a herder or 'range rider' to move livestock while also providing real-time monitoring of livestock and investigating more closely the causes of the livestock losses (as these are often attributed incorrectly to predator activity) (Brown 2011; Stone et al. 2017). However, producers should not be expected to develop alone the necessary depth of 'ecological literacy' required for successful active management. Wildlife agencies and NGOs must collaborate closely to engage producers in dialogue that could foster a greater understanding of stakeholders interests and goals.

In each model the pathways focus on institutional support to facilitate adoption of preventive innovations (P2, P3 in the South African model and P2, P4 and P5 in the USA model).

Support is often needed to overcome the barriers to adoption of preventive innovations and include financial and policy incentives and capacity building, which are vital for change creation (Chan et al. 2020). For example, in both countries financial support or cost sharing of investment with producers by NGOs, government agencies or industry bodies is evident, i.e. the Landmark Foundation in South Africa and the Wood River Wolf Project in Idaho, USA. NGOs purchased deterrents including livestock protection collars and aversive technology (lights and horns) that were loaned to producers, along with training on their deployment (McManus et al. 2015; Stone et al. 2017). These initiatives encouraged greater adoption by sceptical producers over the longer-term. Similarly, Rust and Marker (2013) reported that subsidising the cost of livestock guarding dogs, kraal building materials and herder wages would be more effective than compensation in promoting practice adoption in Namibia. However, financial incentives alone may be insufficient to stimulate adoption of preventive innovations and wildlife tolerance (Naughton-Treves et al. 2003; Dickman et al. 2011).

While NGOs and government agencies have a role to play in providing institutional support, a more powerful tool to facilitate adoption is social learning via peer-to-peer support and training from within agricultural communities (Rodela 2011). Each model contains pathways focused on activities that build producer capacity (knowledge, skills and competencies) to choose and adopt preventive innovations suited to their particular context. Farmers in general are viewed as innovators, continuously adapting technology and practices to changing environmental conditions and socio-economic circumstances (Pannell et al. 2006). However, individuals vary in their degree of pro- and re-activeness in the adoption of new tools and practices, which can affect the wider achievement of sustainability goals. Pannell and Vanclay (2011) identified many conservation practices as preventive innovations and discussed two key factors that increase the likelihood of adoption i.e., high relative advantage (i.e. the new practice is superior to the current practice); and, trialability (the practice or innovation can be tested and learned about prior to adoption) (Pannell et al. 2006; Pannell and Vanclay 2011). Trialability is affected by technical attributes of the practice such as cost of on-farm experimentation, the scale of adoption required, the observability of the results and the complexity of the innovation (Pannell et al. 2006; Pannell and Vanclay 2011). Social networks provide valuable sources of knowledge and experiences that farmers draw upon for reference (Leys and Vanclay 2011). This is because individuals are generally more receptive to information from people they consider to be within their own reference group (i.e. people of similar livelihood, gender, economic status, geography, beliefs or values) (Stern 2018). van Eeden (2020) found that a social identity, such as farmer or animal rights advocate, is a strong predictor of attitudes toward wildlife

management. Peer-to-peer training also fosters strong social connections and encourages collective action through the creation of social norms (Amel et al. 2017). Knapp and Fernandez-Gimenez (2009) found that informal social networks and formal peer learning networks are used by ranchers in Colorado to acquire new knowledge. Demonstration of successful adoption of preventive innovations by producers generally encourages adoption by other local producers as they have seen how it works in their local context, thereby, lowering their risks (time, cost, failure) of adoption and increasing the perceived credibility of the practice facilitating adoption clusters (Pannell et al. 2006; Pannell and Vanclay 2011).

There is a clear need for ongoing research into the effectiveness of the range of preventive innovations in various contexts to fill current knowledge gaps (Stone et al. 2017). Pathways that address the need for such research appear in both the USA and South African models and are supported by findings suggesting that the willingness of producers to adopt such innovations often relies on proof of their efficacy (Young et al. 2019). However, many innovations may not suit all grazing systems, may be impractical to deploy in some situations or may not offer universal protection from all carnivores (Baker et al. 2008). Engaging farmers in research to identify and fill these research gaps is therefore important. Furthermore, there is an array of complex variables affecting predation rates including terrain, vegetation, alternative prey availability and season, as well as biology and behavior of the carnivore species of concern, such as territoriality and cognition, which influence the success of preventive innovations in specific situations (Baker et al. 2008). For example, a number of studies have proven the general effectiveness of livestock guardian dogs (LGDs) (van Bommel and Johnson 2012; van Eeden et al. 2018a, b; Spencer et al. 2020). However, in the USA when wolves have young pups in a den between April to June they may attack and kill LGDs to defend their pups, so alternative preventive innovations should be used during this period (Stone et al. 2017). Involving producers in research and decision-making may imbue a sense of ownership over the solutions as well as embed stewardship values. In Wilson et al. (2005) ranchers were engaged to provide geographical information on human activities in the landscape that may attract bears such as calving areas and beehives. This information was then used to build a geo-spatial picture of potential conflict hotspots and inform predation reduction strategies. Furthermore, Colloff et al. (2017) found that knowledge co-production between researchers, practitioners, and citizens "supports collective action and reflection directed towards improving the management of human and environmental interrelations" (Colloff et al. 2017, p. 1013). This is echoed by Ives et al. (2020) who assert that "effective action for sustainability is increasingly understood to require not only systems knowledge (technical knowledge of how systems function) but also normative knowledge (how systems ought to be), and transformative knowledge (how to change systems to more desirable states)" (Ives et al. 2020, p. 212). As this paper has shown engaging various stakeholders is critical as there is more than one way of defining the challenge of human-carnivore coexistence, and a need to include various sources of knowledge to identify pathways towards a transformed future.

Increasingly consumers have a role in supporting producers that adopt predator friendly practices. P6 in both models focusses on predator friendly certification and labelling to foster coexistence between humans and carnivores in livestock grazing enterprises. NGOs such as the Wildlife Friendly Enterprise Network with the *Predator Friendly* label (http://www.predatorfriendly.org) and the Landmark Foundation in South Africa which operates under the label *Fair Game* support producers that refrain from lethal carnivore control, diversify markets and satisfy a growing demand. During each interview producers were asked about their willingness to participate in such a program. Overall non-lethal producers in both countries did not consider the economic benefits alone to be a sufficient reason to adopt predator friendly tools and practices. Yet when considered holistically alongside the benefits for livestock and landscape health, producers agreed that this type of labelling scheme could provide recognition of important ecological stewardship efforts. This finding aligns with research about Predator-Friendly Beef Certification which found that ranchers in Washington, USA that were in favor of predator-friendly beef labeling were compelled by the consumer education and outreach opportunities rather than a new source of income (Bogezi et al. 2019). In our study lethal producers were not in favor of such a labelling scheme as they felt that predation costs might outweigh the premium received and did not want to be seen by neighbors and peers as being 'friendly' towards predators, a finding also reported in Bogezi et al. (2019). However, all producers rely on consumer demand for their products and favored exploration of ways to diversify their markets.

The vision of a preferred future synthesised in each of the models was remarkably similar and focused on three key areas: carnivore conservation to maintain ecosystem resilience, sustainable rural communities and the empowerment of stakeholders in the governance of natural resources. In both models, conservation goals included the recovery of the populations of carnivores and safeguarding carnivores from human persecution. Stakeholders articulated that mitigating human wildlife conflict and fostering coexistence would require new management practices such as PSF to become mainstream in extensive grazing systems. Policies that support preventive innovations and research combined with effective enforcement of regulation coupled with policies to deter carnivore persecution and illegal killing were central to

achievement of a transformed system. Producers envisioned an agricultural system that supports and sustains rural communities and livelihoods and healthy productive landscapes in which livestock are safe and less vulnerable to all threats.

Conclusions

In the context of global sustainability, the notion of transformation is increasingly used to characterise aspirations to transition from current unsustainable and inequitable mechanisms toward a more sustainable, inclusive, and equitable future (Patterson et al. 2017; O'Brien 2018). We present two transformative change models that examine human-carnivore coexistence in extensive rangeland grazing systems in South Africa and the United States. The models were developed through extensive engagement with 85 stakeholders (livestock producers, landholders, government and representatives of conservation NGOs) using an integrative sustainability framework (Sellberg et al. 2017). Pathways to coexistence that encompass a range of stakeholder perspectives are a major contribution towards human dimensions of conservation. Without bold action to transform our current systems, we risk losing one million species within decades (Ripple et al. 2017; Ferrier et al. 2019). Consequently this paper articulates the essential pathways to intervene in the current social-ecological system to facilitate outcomes that are more equitable and just for multiple species. An important finding is a new concept of Predator Smart Farming, a holistic and conscientious approach to agriculture to increase the resilience of landscapes, animals (domesticated and wild) and rural livelihoods. The two models developed here show the pathways towards incremental, equitable and just transition from the current system towards a future system that realizes multiple desirable outcomes including diverse and thriving rural livelihoods, biodiversity conservation and maintenance of ecosystem services, and more peaceful, just, and compassionate relationships with animals.

Author contributions LB conducted the data collection (workshop and interviews), analysed the data and drafted the majority of the manuscript. Dr J conducted the data collection (workshop and South African interviews), assisted with analysis and interpretation of results, contributed to the discussion and reviewed the manuscript. Dr W assisted with identifying and recruiting stakeholders to interview, helped to refine thinking and interpretation of results. Dr. MM reviewed the manuscript and contributed to refining the South African model and clarified the South African context. SS identified and assisted with recruiting American stakeholders to interview, reviewed and contributed to the United States model and clarified the US context. SS identified and recruited American stakeholders to interview, reviewed and contributed to the United States model and clarified the USA context. Dr. S identified and recruiting South Africa stakeholders to interview, reviewed and contributed to the South African model and clarified the country context. HZ contributed ideas about human-carnivore coexistence, the need for financial resiliency on ranches to foster coexistence and refined thinking in the manuscript.

Data availability The interview questions are available to review upon request and/or can be provided as supplementary material.

Code availability MAXQDA software (VERBI GmbH version 18.2.0).

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval ETH18-2568—HREC University of Technology Sydney.

Consent to participate All of the stakeholders engaged in the research provided informed consent to participate in the research.

Consent for publication I declare that this is original work and has not been published before, nor is it under consideration for publication anywhere else. This publication has been approved by all co-authors as well as by the responsible authorities.

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Chapter 6: Ahead of the herd - What distinguishes predator-smart from conventional livestock producers?

In this chapter, I argue that barriers impede progress towards coexistence and entrench the current regime of lethal management of carnivores. The lack of progress is evident in the low rates of adoption of technical solutions (identified in Chapter 5) in stakeholder developed transition models) that would unlock the benefits of coexistence. Innovative producers, that is those who had adopted preventive non-lethal innovations to protect their livestock and livelihoods, reaped the benefits of coexistence. Benefits included reduced time spent on lethal control, enhanced livestock and landscape resilience, and access to novel markets and new customers who share similar values. However, many producers have not transcended the barriers and continue to employ lethal practices to reduce predation risk.

Over the course of the stakeholder interviews, it became apparent that livestock producers face a range of barriers when considering whether to adopt preventive non-lethal innovations. This Chapter explores the reasons behind the continued use of lethal control of large carnivores by exploring barriers to the adoption of non-lethal alternatives. The Chapter has been written in the form of a draft manuscript for submission to a peer-reviewed journal.

Abstract

Preventive non-lethal innovations to reduce predation on livestock are increasingly advocated as a better way to align animal agriculture with wildlife conservation and animal welfare. Despite global case studies demonstrating the effectiveness of preventive innovations to mitigate human-carnivore conflicts, their adoption by extensive livestock producers is yet to become mainstream. This chapter aims to identify the most significant barriers to adoption of preventive innovations. These innovations aim to reduce human-wildlife conflict that are beneficial for both humans and wildlife. Drawing on interviews with 45 stakeholders (industry, government, researchers and environmental advocates) in South Africa and the US, I explored the factors that create barriers to a broader adoption of preventive innovations. I used thematic analysis to classify barriers to adoption across three spheres of influence: practical, political and personal. Livestock producers generally encountered barriers across all three spheres. A key finding is that barriers in the political sphere comprising of socio-cultural, institutional and economic factors reinforced lethal approaches among conventional producers regardless of the efficacy or economy of alternatives. However, a growing number of innovative producers have successfully overcome the myriad barriers. Insights from the personal sphere revealed five key areas where innovative producers differ from producers that used lethal control of carnivores (conventional producers). Innovative producers: (1) had a more expansive or holistic worldview, (2) prioritised long-term ecological health over short-term economic gain, (3) had a greater capacity for self-reflection, (4) were able to tap into a supportive network, and (5) were more open to new ways of thinking and scientific information. These findings are critical for conservation programs that aim to conserve large carnivores in human dominated landscapes.

6.1 Introduction

Pastoralism, the dominant terrestrial land use worldwide (Fischer et al. 2006; Mottet et al. 2017), significantly influences the health and wellbeing of human and non-human communities (Machovina et al. 2015). Lethal carnivore control by pastoralists exacerbates global challenges, such as loss of ecosystem resilience, loss of biodiversity, and poor animal welfare. There is growing recognition of the need for alternative approaches that support sustainable agriculture and diverse livelihoods while also conserving biodiversity, and human and other animal welfare (Fischer et al. 2006; White 2008; Heller and Zavaleta 2009; Fernandez et al. 2013; Didarali and Gambiza 2019). This evolving approach to agriculture has spurred alternative forms of food and fibre production that focus on ecological resilience. Alternative forms of production include agroecology (Altieri 1989; Wezel et al. 2009; Fernandez et al. 2013; Iles 2021), regenerative grazing (White 2008; Massy 2017), Holistic Resource Management (Savory and Butterfield 1999), Wildlife Friendly Farming (Johnson and Wallach 2016; Schurch et al. 2021) and Predator Smart Farming (Boronyak et al. 2021).Wildlife Friendly Farming focuses on accommodating the needs of wildlife in landscapes dominated by agriculture. Wildlife Friendly Farming benefits conservation by increasing the richness and relative abundance of species (Schurch et al. 2021).

These new farming movements strive for inclusivity of wildlife, which attempts to conserve biodiversity on land that is simultaneously used for agricultural production (Johnson and Wallach 2016). Despite the concept of Predator Friendly Farming showing much promise and being attractive from a conservation standpoint, the term has achieved limited traction with livestock producers. A key finding in chapter 5 is the need for community sensitive language that can appeal to rather than alienate the audience you are trying to engage. For example, the term Predator Friendly Farming has achieved limited traction with livestock producers. During my in-depth interviews with producers in South Africa and in the US, I noted a negative reaction to the term 'predator friendly'. There appeared a reluctance to be 'friendly' towards wildlife with 'big teeth and claws' and that has the potential to harm livestock and livelihoods. A rancher from Oregon proposed the term 'predator smart' which generated more favourable reactions from other producers when I tested the concept, and therefore, I use this term throughout the remainder of the thesis.

Predator Smart Farming combines aspects of ecologically sensitive and sustainable farming practices, such as agroecology and Wildlife Friendly Farming, into a holistic and conscientious approach to farming. Predator Smart Farming aims to increase the resilience of landscapes, animals (domesticated and wild) and rural livelihoods (Boronyak et al. 2021). The key distinction between Wildlife Friendly Farming and Predator Smart Farming is that Wildlife Friendly Farming focuses on accommodating the needs of wildlife in landscapes dominated by agriculture. Whereas Predator Smart Farming focuses on people, their values and livelihoods, as well as conservation and animal welfare benefits (see Figure 10). Predator Smart Farming focuses on the holistic considerations of producers, rather than simply tools and practices that are non-lethal to carnivores. Predator smart farming has three key aspects:

1) Reducing vulnerability: the adoption of preventive innovations and livestock husbandry to reduce the vulnerability of livestock to all risks, including disease, environment, climate, and predation.

2) Increasing landscape resilience: focusses on social-ecological stewardship that encourages ethical and responsible interactions within Social-Ecological Systems to maintain the underlying ecosystem and landscape processes, as well as values for humans and other life on the planet (Cockburn et al. 2018; Gosnell et al. 2019).

3) Resilient livelihoods: approaches that reduce the costs and capitalise on the benefits of large carnivores in the landscape. For example, healthy populations of carnivores may reduce grazing pressure from wild herbivores that contributes to increased pasture growth critical to grazing enterprises (Prowse et al. 2015). Being financially resilient also means that a predation event will not cause a significant shock and financial strain.
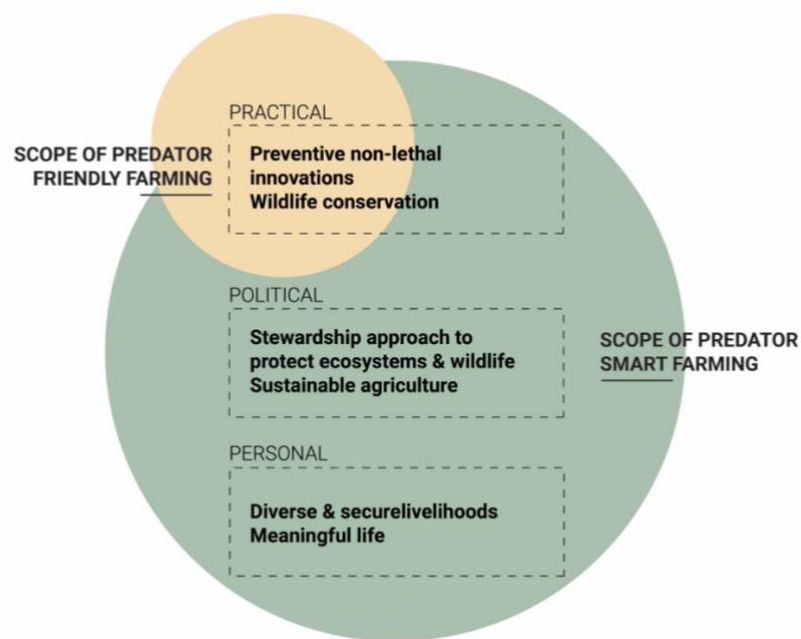
Figure 7: Scope of Predator Smart Farming versus Predator Friendly Farming

At its core, Predator Smart Farming advocates for coexistence between humans and carnivores, aided by the adoption of preventive innovations (Stone et al. 2017; Boronyak et al. 2020). Predator Smart Farming advocates the adoption of preventive innovations, where appropriate, to deter carnivores from areas being used to graze livestock; guard or enclose livestock and reduce livestock vulnerability to predation risk. Predator Smart Farming shifts the focus from predators to improving the management of livestock (Stevenson pers. comm), the land and rural livelihoods to increase resilience to all threats where possible. This expanded perspective provides greater alignment with what livestock producers value. It integrates thinking about whole systems, wildlife ecology, behaviour and landscapes as part of the farming enterprise.

Predator Smart Farming integrates ecologically sensitive and sustainable practices from agroecology and regenerative grazing to intentionally increase the resilience of livelihoods, landscapes and livestock. This approach has the potential to be more effective in the long run, in terms of mobilising support and creating collaborative partnerships for human-wildlife coexistence. This is because change cannot be instigated without the involvement of key stakeholders and the adequate representation of their views and perspectives (Pretty 1994).

Despite their potential and importance in sustainable agriculture, alternative types of farming remain niche. Sustainable transformation of agricultural systems is urgently required to address the challenge of feeding a growing world population while halting the degradation of ecosystems that supports life on earth (Rockström et al. 2017; Iles 2021). The agri-industrial nature of farming systems in the developed Western world often imposes barriers to the adoption of sustainable agricultural innovations (Pannell et al. 2006; Rodriguez et al. 2009; Didarali and Gambiza 2019; Gosnell et al. 2019; Iles 2021). In this context, barriers are factors that impede wide-spread adoption of tools or practices that aim to increase environmental resilience in agricultural landscapes (Pannell et al. 2006; Rodriguez et al. 2009).

A systems-based approach can be useful to diagnose the complex social, political, economic, and environmental barriers that impede adoption of more sustainable agricultural practices (Meadows 1999; Waudby et al. 2020). An intervention or 'leverage point' is a place in the system where a small change could lead to a large shift in system behaviour (Meadows 2008). The leverage point framework enables the identification of interventions with different levels of potential to create change in complex systems (Davila et al. 2020). This framework has been conceptualised across three areas or 'spheres': the personal, practical, and political spheres (see (O'Brien 2018) summarised in Chapters 2 and 4). In this chapter, I utilise the three spheres framework to classify barriers to the adoption of preventive innovations.

The personal sphere encompasses individual worldviews, values, identities and priorities and is considered as the deepest motivator of behavior and behavior change (Beddoe et al. 2009; Rigolot 2018; Ives et al. 2020). An individuals worldview combines beliefs, attitudes, values, and ideas to form a model of reality (Schlitz et al. 2010). Sustainability transformations are fundamental and long-lasting, implying a shift in worldview (O'Brien and Sygna 2013). The political sphere encompasses the systems, structures and institutions that govern social, cultural, political, legal, and economic systems. Within the political sphere norms are challenged, social movements are formed to address structural injustices, and interest groups lobby to defend or transform the status quo (Meadows 1999; Meadows 2009). The practical sphere is where specific actions, behaviours, interventions, strategies and technical solutions contribute towards desired outcomes (O'Brien 2018; Gosnell et al. 2019).

Past focus on the transfer of technology in agriculture has over-emphasised the importance of the practical sphere and neglected the influence of personal and political spheres. Neglect of the personal sphere may be due to the deeply held and intangible aspects of this sphere, making it difficult to understand, let alone alter. Deep and broad interventions are required to bring about transformative change in extensive grazing systems, to foster more sustainable agriculture that emphasises wildlife conservation and coexistence. Transformative change requires consideration of all three spheres: practical, personal and political.

The adoption of preventive innovations is potentially a key leverage point for human-carnivore coexistence in agricultural landscapes (Boronyak et al. 2020). Preventive innovations alter the behaviours of humans, livestock or wild carnivores. Globally, preventive innovations have been documented to reduce encounter rates thereby keeping both domesticated livestock and carnivores safe from harm (Shivik et al. 2003; Baker et al. 2008; Rust et al. 2013; van Bommel and Johnson 2014). Examples of preventive innovations in the US include: the use of enclosures (electric fencing, night pens, fladry and turbo fladry) around livestock pastures; intensive livestock and carnivore monitoring provided by producers, herders or range riders; the removal of attractants (carcasses); deterrents; and livestock guardian animals (Stone et al. 2017; Wilson et al. 2017; Young et al. 2019). In South Africa, livestock producers mitigate predation via guardian animals such as dogs (*Canis familiaris*) and alpacas (*Lama pacos*) (McManus et al. 2015; Spencer et al. 2020), livestock protection collars (McManus et al. 2015), human shepherding, and kraaling (corralling) livestock at night (Schurch et al. 2021). Preventive innovations are increasingly advocated to negotiate the trade-offs between wildlife conservation and animal agriculture, yet adoption is impeded by multiple barriers. A key aim of this research is to deepen understanding of the barriers to adoption of preventive innovations across different geographies and cultures to inform conservation programs.

This chapter explores the barriers to transformation across the three spheres (practical, political and personal) by focussing on barriers that create the greatest impediment to the adoption of preventive innovations (O'Brien 2018; Boronyak et al. 2020). This issue is examined from three perspectives. Firstly, what are the major barriers that producers in US and South Africa face when considering whether to adopt preventive innovations? Secondly, what are the most constraining barriers and how do they operate? Thirdly, are there common traits exhibited by more innovative producers that set them apart from conventional producers, and place them 'ahead of the herd' in terms of displaying leadership in ecologically sustainable agriculture?

6.2 Methods

I conducted 45 semi-structured interviews with key informants from the US (25) and South Africa (20). Informants were livestock producers (primarily sheep and cattle graziers) (32), and representatives of government institutions in charge of agriculture and wildlife conservation (8) and non-government organisations that focus on animal protection or the environment (5). Two non-probability sampling procedures were used to collect information. Initially, a purposive sampling procedure to recruit stakeholders with specialist knowledge in livestock production, and wildlife management and policy (Bryant and Charmaz 2010). Followed by a a snowball or network sampling technique to recruit additional stakeholders (Biernacki and Waldorf 1981). These two techniques were used to reduce sampling bias due to the small sample size, but I recognise that bias may not have been eliminated. Interviews were conducted from January 2018 to October 2019, and typically lasted 60-90 minutes. With the interviewee's consent, the interviews were audio recorded and transcribed verbatim. All data were gathered under University Research Ethics Approval from the University of Technology Sydney (ETH18-2568—HREC).

Semi-structured interviews were used to elicit specific information from each stakeholder group (see chapter 3 for detailed methods). Representatives from institutions (NGOs, industry and government) involved in either wildlife management, conservation or agriculture were questioned about the institutional factors that may enable or constrain adoption (e.g., financial support, policies, culture and peer support). Questions were also asked to identify key leverage points that could foster coexistence.

Livestock producers were asked about interactions with carnivores, predation frequency, approaches to mitigate predation (including lethal, preventive non-lethal innovations or a mix of approaches), and the reasons why they had implemented their preferred approaches. If producers had adopted one or more preventive innovations (e.g., deterrents and guarding dogs) or grazing techniques to reduce livestock vulnerability to predation, this triggered additional questions about the challenges faced in adopting these tools or practices. Producers were encouraged to 'tell the story' by sharing personal experiences adopting preventive innovations. This allowed identification of the barriers faced by adopters as well as the processes, events and factors which inspired, facilitated and enabled adoption (e.g., relationships, supports, incentives, local cultural norms).

Interview data were coded and analysed using the Miles and Huberman (1994) model for the thematic analysis process, which consists of three phases: firstly, *data reduction*; secondly, *data display* and thirdly, *data conclusion-drawing.* Data were sorted into themes relating to barriers and enablers to the adoption of preventive innovations using MAXQDA software (VERBI GmbH version 18.2.0). Producers were classified according to their primary approach to managing predation risk: conventional (reliance on lethal practices shooting, trapping or poisoning) or non-lethal (reliance on preventive non-lethal tools and practices). From the US, 16 commercial producers were interviewed. Twelve producers relied primarily on non-lethal tools and approaches (herein innovative producers). Four relied on lethal approaches to manage predation risk (herein conventional producers). In South Africa, 16 commercial producers were interviewed, comprising 9 innovative producers and 7 conventional producers. Thematic analysis revealed barriers to the adoption of preventive innovations that we classified across the three spheres: personal, political and practical (Figure 8). Figure 11 suggests that the spheres are nested. The personal sphere is broader across all of society, whereas the practical sphere relates to agricultural practices within the context of the thesis. Quotations have been used to provide evidence, support and validate interpretations (Miles et al. 2014).

6.3 Results

Four main barriers in the practical sphere were identified including financial: the financial outlay relating to purchasing equipment or infrastructure; social capital: difficulties hiring skilled staff, limited knowledge of how to effectively apply preventive innovations, efficacy: misperceptions about the efficacy of preventive innovations and ecological: carnivore habituation to aversive stimuli. While these barriers were important, they did not appear to be the most constraining barriers, and generally formed the shallowest of Meadows leverage points (Meadows 1999). A number of innovative producers had overcome these barriers.

Analysis showed that political and personal spheres appeared to exert greater influence on decisions relating to carnivore interactions than the practical sphere. Consequently, the results presented here have a stronger focus on the barriers in the political and personal spheres. Barriers in the political sphere related to socio-cultural, economic, and institutional structures, systems and norms. Barriers in the personal sphere included worldviews, values, priorities and identity. After briefly describing barriers in the practical sphere, I will focus on the barriers that caused the greatest impediment to the adoption of preventive innovations in the political sphere because they are less well-documented, are outside the control of the producer and potentially inhibit leverage points towards human-carnivore coexistence. I will then explore barriers to change in the personal sphere, and conversely, how personal characteristics have enabled some producers to be more progressive and ahead of the herd.
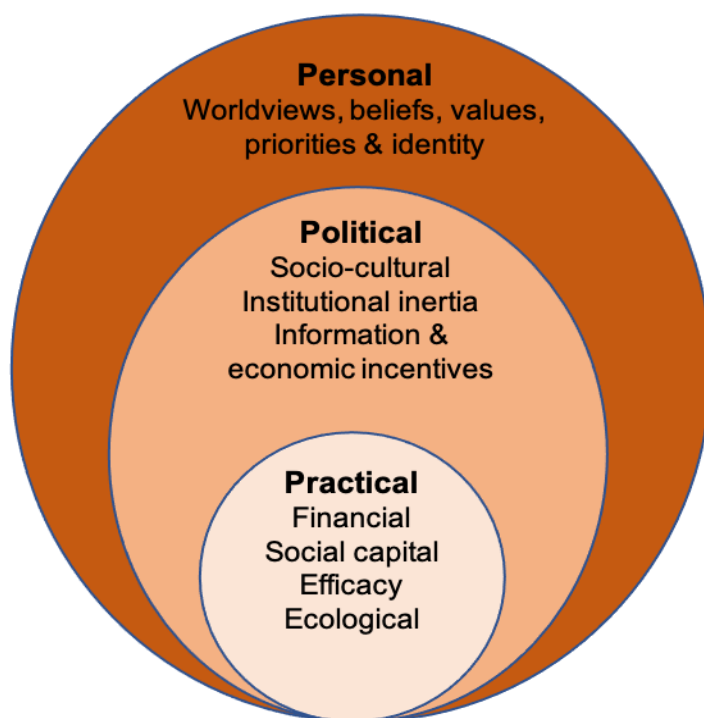
Figure 8: Barriers to preventive non-lethal innovations across three nested spheres

6.3.1 Barriers in the practical sphere

Four key barriers to the adoption of preventive innovations were identified in the practical sphere. These barriers include the investment of resources (time and money), and lack of landholder capacity (knowledge, networks and experience), as well as perceptions of the efficacy of preventive non-lethal tools and practices in large extensive grazing operations. Barriers can also be ecological, in terms of the habituation of carnivores to deterrents or aversive stimuli. Habituation may mean a mix of strategies need to be used. The extent of barriers is summed up in this quote from a US based NGO involved in certifying producers under a wildlife friendly label.

"I think almost all livestock producers in my environs have made substantive changes to the best of their ability. But so much remains out of reach because it is expensive (i.e., more labour or start-up costs), difficult (i.e., more labour and specialised knowledge), or often truly out of reach in terms of learning curve, financial limits, and labour required (e.g., livestock guardian dogs and fladry). There is no silver bullet to be effective. Staying ahead of the game requires a mix of predator friendly practices and regular adaptive management."

NGO representative, Montana, US

A barrier to the adoption of preventive innovations is the perception that preventive innovations are more expensive in terms of resources to deploy than lethal options such as shooting or trapping. Among the interviewees, producers that utilised only lethal control held this perception more widely than innovative producers. The cost of preventive innovations related to time and hiring additional labour with the right skills, expertise, and willingness to spend time checking or guarding livestock. Innovative producers saw the resistance of conventional livestock producers as an unwillingness to invest in their business despite the possible benefits. For example, innovative producers who had hired extra labour to herd and manage livestock believed that the benefits outweighed the costs in terms of environmental improvement, improved time management, and reduced exposure of livestock to predation and other threats.

"People tend to look at the costs attached to having more personnel compared with a situation where they just allow their livestock to just roam around. But then they tend to overlook the adverse effects which tend to happen to their environment, and the fact that the animals are exposed to predation."

Innovative sheep and cattle producer, Northern Cape Province, South Africa

Another important barrier in the practical sphere is the perceived lack of capacity such as skills, knowledge, and experience to implement preventive innovations. There is often a learning curve associated with preventive innovations. If livestock predation occurs during the learning phase, producers may assume the innovations are ineffective, rather than focusing on improving sub-optimal implementation.

There appeared to be a lack of information about local carnivores in terms of their ecology, behaviour, movement and hunting style. This information would inform which risk reduction strategy would best suit the enterprise, location, terrain and carnivore(s). A related ecological barrier is how carnivores can become habituated to aversive deterrents over time, particularly visual or audio deterrents. Habituation may also influence perceptions of efficacy, and the need to change the location or type of deterrent.

6.3.2 Barriers in the political sphere

Analysis identified a range of factors in the political sphere that significantly constrain the adoption of preventive innovations. These factors are external to an individual producer yet influence actions in the practical sphere, and worldviews and beliefs in the personal sphere.

Socio-cultural barriers

A strong socio-cultural element of lethal carnivore control is evident in both the US and South Africa. These socio-cultural factors influence how landholders relate to and interact with other producers and local carnivores. Innovative producers reported encountering social pressure, often in the form of conflict, if they openly supported or used preventive non-lethal tools and practices to mitigate predation. This social pressure included name calling, harassment, arguments, and withdrawal of reciprocal arrangements or favours. There appeared to be deliberate attempts to dissuade innovative producers from deviating from social norms like lethal control of carnivores. This social pressure was experienced by all innovative producers interviewed.

> *"The social pressure is there especially if you're that person on the edge yourself and your friends are going to think you're a traitor, that's a hard thing."*
>
> Innovative cattle producer, Montana, US

> *"There is social pressure, I just withdraw, it's the only way I know of coping with it, rural people are conservative, and that resistance is a built-in factor."*
>
> Innovative sheep and cattle producer, Northern Cape Province, South Africa

> *"When I sit down at the local diner, are the conversations going to stop and people kind of turn away, because now I'm the joker that actually started doing this non-lethal, when everybody knows the best wolf is a dead wolf."*
>
> Innovative sheep producer, Idaho, US

Social conflicts can arise over different values held by individual landholders especially because large carnivores are often highly mobile in the landscape, moving between neighboring landholdings. If one producer chooses to tolerate a carnivore on their land, they may face accusations from adjacent landholders that they are breeding or harboring 'vermin or pests', and face pressure to implement lethal control.

> *"We have been labelled all sorts of things and that is another one, we have been labelled as breeding vermin."*
>
> Innovative sheep and cattle producer, Eastern Cape Province, South Africa

Pressure may be exerted on innovative producers in the form of withdrawal of reciprocal arrangements such as loss of access to grazing lands and social exclusion. In rural communities, this occurs during interactions with neighbours, within a social circle or in dealing with their industry (e.g., at local stock growers' meetings). This social pressure was considered to be a 'big risk' as producers are reliant on their neighbours and local community for support and favours.

"There was a piece of ground I wanted to graze, and the non-lethal deterrent discussion and my public opinion and views on it came up. That the landowner didn't agree with [non-lethal] *and did not want to take part in those types of practices, so I was forced to either not use non-lethal deterrents, to leave or to stay there on uncomfortable terms, in conflict, and that is what we are trying to do is avoid conflict. So that is a big risk."*

Innovative sheep producer, Oregon, US

Concerns about social conflict and retaliation can lead to innovative producers refraining from discussing the topic of carnivores and preventive innovations. Innovative producers had attempted to reduce the chance of being mocked or coerced by withdrawing from places where a conflict may occur (e.g., local restaurant or bar, community event, industry meeting or other social settings), which can lead to further social exclusion and isolation.

"I don't even want to go there [discussing non-lethal options] *because you are farming in communities, and I don't want to be targeted and life could become unpleasant. So, you want to avoid those kind of things…. I have stopped talking about* [livestock guardian dogs] *because then they start avoiding you, they start thinking you are a big deal. They start thinking you are too clever for them."*

Innovative sheep and cattle producer, Eastern Cape Province, South Africa

"I don't go to the bar as much as I used to and I'm careful at social gatherings."

Innovative cattle producer, Montana, US

Lethal producers also expressed concerns over peer disapproval or rejection if they adopted preventive innovations.

"You don't want to get laughed at, so you don't really talk much about it [non-lethal deterrents].*"*

Conventional sheep and cattle producer, Northern Cape Province, South Africa

This social pressure was described by innovative producers as 'backlash' or 'retaliation' to their decision not to kill carnivores on their farms.

"If you're trying something different, you may be stepping out from the norms within the local culture, and that can create a backlash."

Farmer and policy maker, Idaho, US

Culture appeared to exert a strong influence over how large carnivores are perceived and how they should be 'treated' or 'managed'. Innovative producers noted that speaking publicly on carnivore coexistence may make them targets of social conflict, this was expressed as a physical embodiment of the socio-cultural pressure.

> *"I was willing to put my neck on the block so to speak. I got in my share of arguments over this. I acknowledge that it's been noted a number of times that you either are crazy or courageous or something to stick your neck out on this."*

<div align="right">Farmer and Policy maker, Idaho, US</div>

Predominant themes from the US interviews were a strong 'culture' of rugged individualism, utilitarian views of wildlife, and positive associations with hunting as a source of food, recreation and social engagement. These themes create a cultural bias towards lethal control. This may be more evident in ranching communities whose livelihood is highly dependent on natural resources.

> *"The public almost has a blind eye and say, well, of course hunting...they would say, well, I'm not a hunter, but hunting is traditional, and hunting is good."*

<div align="right">Innovative sheep producer, Idaho, US</div>

> *"It's the cultural, social and intellectual environment around* [ranching] *that is not geared to this* [non-lethal]. *We are human beings, we are social animals so that is how we operate, rarely you will find people who are willing to make those decisions to go out on their own and do things. He* [the rancher] *has all of his cultural and societal baggage and if he is in a small rural community and he is friends with all other livestock producers in the community, is he going to be the guy who goes out on a limb to say yeah, I am willing to try this or I am willing to do this, so there is peer pressure."*

<div align="right">Farmer and Policy maker, Idaho, US</div>

Similarly, in South Africa as a colonised country, hunting has a long history that has made it embedded in the culture and considered as a recreational pastime.

> *"In South Africa, these guys are obsessed with jackals and hunting them. It's almost like their hobby, their pastime, their life. It's almost a cultural thing with those kinds of people, they a have been brought up for generations in a certain way. Whether it's the correct thing or the most beneficial thing it's not the point. The point is it must be killed."*

<div align="right">Innovative sheep and cattle producer, Eastern Cape Province, South Africa</div>

> *"They hunt if they liked that social element, my opinion is they enjoy hunting. And it's very difficult for them to abandon that. I think it's also related to...a bit like a social status thing, but then also more than that, I think it gives them some sort of control over these losses. This tangible thing to take out of the system."*

<div align="right">Coexistence researcher and practitioner, Eastern Cape Province, South Africa</div>

The socio-cultural element of hunting was evident to such a degree in South Africa that community-wide hunting of carnivores appeared common. Some conventional producers had become increasingly militarised in the escalating 'war' against wildlife. This is evidenced by the adoption of military thermal scopes to aid night shooting, shooters using purpose-built

vehicles (referred to as buggies), the use of poisons and hiring a helicopter to shoot carnivores in South Africa. The escalation of efforts to kill carnivores is associated with increasing financial expenditure to procure and use this technology. For example, a buggy reportedly costs between 8,000-20,000 rand (550 to 1,370 USD), while hiring a helicopter to aerially shoot carnivores reportedly cost between 4,000-5,500 rand per hour (280 to 400 USD). Contrast this level of expenditure with the 5,000 rand (400 USD) to purchase a livestock guardian dog (e.g., Anatolian and the Africanis Maluti breeds), which, if trained properly, would provide on-going protection of livestock (McManus et al. 2015). It appears that decisions to invest in lethal control were not based solely on finances. Socio-cultural factors appeared to greatly influence decisions relating to carnivore interactions.

Institutional barriers

Federal, state, and local governments form part of the institutional environment of Social-Ecological Systems such as agricultural landscapes. The US Wildlife Services, a division of the US Department of Agriculture's Animal Plant Health Inspection Services (USDA APHIS), forms a major institution governing agriculture and wildlife management in conjunction with state Fish and Wildlife agencies. In South Africa, the institutions that manage wildlife at the national level include the Department of Economic Development, Environment, Conservation and Tourism (DEDECT), and Department of Forestry, Fisheries and the Environment (DFFE).

Institutional barriers to the adoption of preventive innovations differed significantly in the US and South Africa. To mitigate predation risk on agricultural enterprises, producers in the US received significant institutional support from government via the Wildlife Services agency, industry, and environmental NGOs. In contrast, livestock producers in South Africa received very little support with the management of predation wholly undertaken by individual producers.

The institutional environment in the US significantly influenced the management of carnivores in three ways. Firstly, social norms relating to carnivore persecution were often reinforced by government programs that used lethal means to suppress wildlife. Secondly, laws, wildlife management plans (policies), and information that government agencies provided to landholders, influenced what actions landholders were aware of and were permitted to undertake. Thirdly, over the long-term, landholders have come to expect and rely on government funding and services that prioritise and subsidise lethal carnivore control.

> *"The history of predator control in this country started back in 1880's and became more refined. So there has always been this dependency on government coming to your aid."*
>
> Former government agent, Idaho, US

In the US, as populations of wolves and bears began to recover (i.e., no longer classified as endangered under the *Endangered Species Act 1973*) their management was transferred from the Federal jurisdiction, under the U.S. Fish and Wildlife Service, to state agencies. State policies and a species' population status emerged as factors that influence the perception and treatment of carnivores. State policies may facilitate or constrain the continued recovery of large carnivores in states where they had been eradicated.

"Delisting will reduce the chances of wolves recovering in those states [Washington & Oregon]. *Because there will be more management flexibility to kill wolves…they can take liberty now to give kill permits to ranchers who claim they have problems so they go ahead and kill some so the state can fly in and shoot them with a helicopter if they need to."*

<div align="right">Former government agent, Idaho, US</div>

When lethal control is framed and sold to landholders as a government 'service' it builds a reliance on the lethal paradigm. For example, the use of helicopters to shoot wolves and coyotes in the US may provide a temporary 'fix', yet there is an expectation that this service will continue to be provided. A notion has evolved that a rancher could call Wildlife Services and the predation problem could be 'dealt' with by a government agency. Government support is also lobbied for by ranchers, which further entrenches a system of lethal control, and significantly impedes alternatives.

"The help they [ranchers] *have been getting for a century from the US Government with its trappers, hunters and airplanes and helicopters, and traps and snares and shooters at the request of a phone call. I was one of those guys for 26 years and know intimately how that whole system functions. After a while it almost becomes an expectation and a right."*

<div align="right">Former government agent, Idaho, US</div>

Livestock industry policies and funding can also reinforce lethal carnivore control. For example, the collection of money (levies) from all producers, creates a pool of funds which appears to be largely spent on lethal options especially in states such as Idaho. Despite, some innovative producers being ethically opposed to lethal control, the system is set up in a way that their levies contribute towards funding lethal options.

"I pay for lethal control because I sell lambs and I sell wool, and there are values that are extracted from my gross receipts that go to different organisations that provide part of the funding for the Idaho wolf livestock depredation control fund, so whether I like it or not, I'm funding the machine. The policy issues are so deeply ingrained that it's not possible, even for a grass-fed operator with our commitments and philosophy to completely extract themselves."

<div align="right">Innovative sheep producer, Idaho, US</div>

Over the last decade in the US, institutional support from environmental NGOs has become a prominent alternative to lethal control. NGO support is intended to overcome barriers in the practical sphere such as offsetting costs or building landholder capacity to implement preventive innovations. NGOs also aim to increase producer tolerance and conserve carnivores.

In contrast to the US situation, South African producers received limited institutional support from government to carry out lethal control, and only a few NGOs were actively focused on building the capacity of South African producers to adopt preventive innovations. In South Africa, it appeared to be common that neighbours or groups of local landholders pooled resources for coordinated regional efforts in the form of ground or aerial shooting, trapping, poisoning and hunting with hounds. In effect, producers created their own institutions to implement control measures.

> "We have a couple of guys that are really good at shooting. Last year we paid these guys to come in and they sweep through the whole of the town. The district union, everybody puts in money there. These guys come in and they clean out [carnivores]."

<div align="right">Conventional sheep and cattle farmer, Free State, South Africa</div>

> "Last time we did shoot with a helicopter. It's been a new practice that is coming in this area, friends of ours actually bought a helicopter. To cover more ground, you can do it early mornings they [jackals] are quite active early mornings. We shot 6 that one morning in an hour and a half."

<div align="right">Conventional sheep producer, Free State, South Africa</div>

Economic barriers

A prevalent economic barrier in the practical sphere is that preventive innovations are more expensive than lethal options. However, the contexts are vastly different between the countries. There is significantly more government funding available for lethal control in the US than in South Africa. For example, the US Wildlife Services can assign agency representatives to trap or shoot carnivores after a predation event has occurred. This institutional policy creates an economic barrier to the adoption of preventive innovations as public funds are allocated for a private benefit. Innovative producers, on the other hand, are paying for biodiversity which is considered a public good. In some US states, producers could access financial support from environmental NGOs for preventive innovations such as electric fencing or fladry. However, some producers chose not to access this support for fear of social repercussions from their local community or because they were not convinced of the efficacy of preventive innovations.

> "It seems here that you have a depredation event and then you pick up the phone and Wildlife Services deals with that, and that's no cost to you. But trying all the non-lethal stuff is a real investment in terms of time and cost of having to hire another person to herd the sheep, or range riding. So really the odds are stacked against it."

<div align="right">NGO representative, Montana, US</div>

"The helicopters are really expensive. You've got to have the pilot to fly the machine, the sharpshooter, insurance, petrol and maintenance, so then typically all of that is compounded in the price per hour. A thousnd dollars an hour to run one of those machines, and then it might fly for days. So, it's not unheard of to see 30,000, 40,000 or 50,000 U.S. dollars per dead wolf, and the operator doesn't pay it, the taxpayer pays that."

Innovative sheep producer, Idaho, US

Interviewees reported that there is growing public resentment over tax dollars being spent on lethal carnivore control. This resentment is contributing to an anti-ranching sentiment across the US, especially when public funds are spent on killing wildlife on public land used for summer grazing of livestock.

"A lot of people resent paying a federal agent to go out and shoot animals that they are attracted to…. The taxpayer pays for their wildlife managed by the state, but held in trust for the citizen, on public land to be killed for the private benefit of the operators, who do not have a grazing right, they have a grazing preference to be able to graze that landscape. The taxpayer then provides all the additional services to make sure that their animals are not killed."

Innovative sheep producer, Idaho, US

Socio-cultural barriers

Socio-cultural barriers to the adoption of preventive innovations are apparent in both countries. There are socio-cultural pressures to continue the tradition and norm of lethal control. Institutional barriers are more significant in the US due to widespread support (policies, and financial resources and personnel) for lethal control.

In the US, culture and institutions act to reinforce this lethal carnivore control paradigm. However, to counter this culture and challenge this paradigm, NGOs have established programs specifically to support producers to transition away from lethal control to adopt preventive innovations. Furthermore, partnerships have been formed within specific geographical regions to encourage more sustainable agriculture, landscape resilience and coexistence with wildlife. While some inroads have been made, it has been insufficient to destabilise the dominant paradigm of lethal control.

In South Africa, cultural norms around killing carnivores and the lack of institutional support, lead to producers forming groups to pool resources to manage the impacts of predation on agriculture. When local producers work together to remove carnivores from a region this creates a social incentive to continue lethal control. Despite this situation, innovative producers had successfully transcended barriers to change and were capitalising on the benefits of human-carnivore coexistence.

6.3.3 Barriers and enablers in the personal sphere

Aspects of the personal sphere such as worldviews, values, beliefs and priorities can be a barrier or an enabler to the adoption of preventive innovations. In this section I discuss the differences in the personal sphere between producers who favoured preventive innovations from producers who preferred lethal control.

Innovative producers who had overcome barriers to adopt preventive innovations appeared to possess worldviews, values, beliefs and priorities that set them apart from conventional producers. Characteristics that appeared to differentiate innovative from conventional producers, including: a holistic world view, an openness to learning, a drive to find innovative solutions, attunement to nature in the form of a desire to observe and understand nature, gratitude, compassion for other species, and surrendering the need to control nature. In contrast, characteristics such as linerar and mechanistic way of thinking, dominion over nature worldview and value orientation, belief in lethal control to reduce predation and priortisation of livestock over other wildlife in the social ecological system.

Innovative producers appeared to possess what could be considered a more expansive or holistic worldview. Their worldview encapasulated beliefs that carnivores are a vital part of ecosystems, with ecological value in terms of landscape health and function. They valued the contribution of carnivores to the ecological resilience of livestock production systems. They understood the role of carnivores in reducing grazing pressure from native herbivores, thus improving the condition of rangelands.

> *"We realised as producers, some of us do anyway, those critters probably have a place on the landscape. They were here and then they were killed off."*

> Innovative cattle producer, Montana, US

> *"I accept that they [predators and other wildlife] are part of the biological system that I am a part of absolutely."*

> Innovative sheep and cattle producer, Northern Cape Province, South Africa

> *"These animals have a place on the landscape. They play an ecological role…the fact is, that wolves do play an important role in ungulate management, and I can tell you that wild ungulates have had a real impact, a negative impact on our range conditions."*

> Innovative sheep producer, Idaho, US

Innovative producers recognised the tension in values between agricultural productivity and the persistence of biodiversity, but they believed that a balance could be achieved without 'wiping out' carnivores.

> *"Most ranchers care about life. Most ranchers care about the environment, because if we don't have the healthy environment, we're out of business. But we're also protectionist, too. We want to protect our livelihood, and then that's where this conflict about predators comes in. There's room for us all. There's room for predators and ranchers. There's no need to wipe out all the predators."*

> Innovative sheep producer, Oregon, US

Innovative producers tended to hold a holistic view of the landscape and considered themselves as stewards of the land. This holistic worldview acknowledges interconnections within ecosystems, connections between soil microbes, grass and the herbivores that consume the grass, and carnivores that feed on the herbivores.

"Being associated with the holistic resource management movement, there is a lot of sympathy for non-lethal control of predators. That is the assumption that you will work along that way, and we have been happy to be part of that."

Innovative sheep and cattle producer, Northern Cape Province, South Africa

"It isn't just about wildlife management, and it isn't just about livestock management. It's about really all three, the livestock, the wildlife, and the people. And if you sort of start with that in mind, it becomes easier...If you're managing the grass, so that there's enough natural feed for coyotes and wolves, whether it's rodents or ungulates, then they're less inclined to go after livestock."

Innovative sheep producer, Montana, US

Innovative producers' holistic worldview may lead to greater consideration of the entire socio-ecological system when making business decisions. These producers may be more inclined to prioritise long-term ecological health over short term economic gain.

"Compromising the ecological for the sake of the economical is not a good strategy for us, and it just doesn't feel good."

Innovative cattle producer, Montana, US

"We believe not only in our commitment to being predator friendly, but also we believe that it's good for our business. And let's just say, that the alternative behaviour [lethal control] *would be really bad for our business*."

Innovative sheep producer, Idaho, US

Innovative producers were more likely to perceive themselves as being an integral part of nature, rather than being separate from and having dominion over it.

"I don't really feel like ranchers have the right to say we're the most important people on earth and so we should kill all the wildlife, because we're more important. I just don't buy it, and I don't think most human cultures buy it."

Innovative sheep producer, Montana, US

"We are in a very fortunate position that we can be involved with nature but try to embrace it and try work with it not against it. I think that is what I have learnt in all my years of farming."

Innovative sheep and cattle producer, Eastern Cape Province, South Africa

In contrast, conventional producers appeared to hold a worldview and value orientation that sees humans as separate from and dominant over nature. Conventional producers believed it was necessary to use lethal means to protect livestock and rural livelihoods. They viewed killing carnivores as the only option. Conventional producers may lean towards linear thinking (i.e., eradicate carnivores to improve farm profitability), rather than thinking in more complex terms that reflect social-ecological systems.

> *"We are farming here. We've got to make money. We are the apex predators."*
>
> Conventional cattle producer, Northern Cape Province, South Africa

> *"This default position is a traditional one, the traditional mindset is that the cheapest solution is a bullet."*
>
> Farmer and government representative, Idaho, US

All producers considered the efficacy of various methods to mitigate livestock predation. They had a belief in the value of lethal control to reduce predation, despite experiential evidence to the contrary, and recognition that other carnivores will fill the vacated territory. Although many producers believed in lethal control methods, their stories supported evidence from researchers that removing local carnivores does not guarantee less predation. For example, a producer in South Africa who had shared the cost to hire a helicopter with his neighbor to aerially shoot carnivores, reported that depredation had worsened after local jackals were killed.

> *"When they used the helicopter, they killed 22 jackal…I lost 25 sheep in the next 2 weeks, and I still had to pay the bill for the helicopter."*
>
> Conventional sheep producer, Free State, South Africa

Lastly, some conventional producers perceived carnivores to be 'unclean', necessitating action to make the landscape 'pristine' by removing carnivores.

> *"The cleaning out* [region wide carnivore removal] *throughout really worked, you have cleaned as much as possible, whereas previously my neighbour and myself cleaned and then we had all the ones* [carnivores] *coming in from outside. If you shoot clean as wide as possible, otherwise you are just going to bring in* [more carnivores]. *Its factual eh? If they* [jackal] *feel threatened they breed more."*
>
> Conventional sheep and cattle producer, Free State, South Africa

Human conflict over wildlife is evident in the perceived benefits and costs of carnivores. Wolves may be perceived negatively by some ranching communities (e.g., Montana and Idaho) due to reintroduction by the US Federal government. A common theme that emerged from speaking to producers, especially in Idaho, is the belief that the reintroduction of wolves was a government intervention that directly impeded their individual freedom to farm. This has caused resentment in rural communities who felt they were not consulted and has likely tainted the perception of wolves and wolf recovery across western US.

"Wolves in particular were seen as symbols of greater societal conflicts, particularly as a symbol of government imposition or proxies for government intervention."

Former government agent, Idaho, US

Resentment around the lack of community consultation in the re-introduction may have led to negative social stigma of preventive innovations. As some producers perceive preventive innovations as attached to an agenda of keeping carnivores in the landscape, which for some individuals can create a personal barrier to adoption.

"The stigma is that if you use non-lethal tools, it means that you're against killing wolves. So, it's like an either/or mindset… Unfortunately, these [non-lethal] *measures that are pretty practical, in some cases, people associate with this agenda of keeping more wolves on the landscape or growing the wolf population."*

Government representative, Montana, US

The killing of carnivores is considered as the 'default position', a traditional approach cementing a particular worldview. Producers who favour lethal options seem unwilling to consider new ideas and evidence from research.

"If you walk into a room full of livestock producers who are not exposed to these ideas, of course they are just going to devolve to the default position, we already have this handled, we don't need this. This is more work for us this is going to cost more money. My point is that there is no cultural or societal support for changing the mindset."

Farmer and Policy maker, Idaho, US

Nevertheless, some innovative producers did change their mindset. They had undergone a fundamental shift in worldview that led to long-lasting changes in their sense of self, relationship to the world around them, and way of being. This is evidenced by them initially implementing lethal options to kill carnivores. At some point they came to realise that lethal control was no longer aceptable, and no longer aligned with their values.

"I was well schooled in killing with gin traps in particular, and I went to training courses. I initially sent staff to training courses. I came to the conclusion that it was a waste of time we were catching other things, we were not catching predators."

Innovative sheeep and cattle producer, Northern Cape Province, South Africa

Shifing worldviews led innovative producers to accept and tolerate carnivores in the landscape, while protecting livestock by implementing preventive non-lethal tools and practices.

"I wasn't welcoming of predators, but they're here. It's a fact of life so we feel like we just need to live with them. And so that's where the non-lethal means of dealing with it comes in versus lethal means."

Innovative cattle producer, Idaho, US

6.4 Discussion

This study exposed multiple, interconnected barriers to the adoption of preventive innovations across the personal, political and practical spheres. These barriers constrain progress towards the adoption of preventive innovations in extensive livestock grazing. Producer-carnivore-livestock interactions occur within social–ecological systems that have social, economic and ecological enablers and constraints (Zimmermann et al. 2010). Barriers, particularly in the political sphere, are real and heavily constrain livestock producers. A combination of deeply ingrained socio-cultural factors passed across generations, appeared to shape barriers in the political sphere. The pressure on innovative producers that dared to 'stray' from the prevailing culture is reinforced by institutional policies. Information and economic incentives from industry and government are also inherently biased towards lethal carnivore control.

The discussion explores these barriers in the political sphere (socio-cultural, institutional, and economic) in depth and aims to explain why they perpetuate the current lethal regime. The political sphere can serve as an obstacle, enabler and arbiter in facilitation of transitions towards sustainability (Meadowcroft 2011). Furthermore, as Treves and Karanth (2003) argue coexistence between humans and carnivores depends on tolerant socio-political landscapes, and favourable ecological conditions. The discussion then moves to transformations in the personal sphere that normalises and empowers communities to coexist with carnivores.

Socio-cultural barriers

Socio-cultural pressure in rural communities emerged as a significant barrier to the adoption of preventive innovation in the US and South Africa. All the innovative producers experienced socio-cultural pressure for choosing not to kill carnivores. This may be because the prevailing culture and social norms in rural communities tends to favor lethal carnivore control. Farming is a socio-cultural practice shaped by social processes and norms (Pannell and Vanclay 2011). Social pressure to conform to local norms can take the form of informal rejection or sanctions (O'Brien 2018; Stern 2018). These rules and norms can trap people within harmful social arrangements (Pretty and Smith 2004). For example, innovative producers faced social pressure in the form of verbal abuse, refusal of reciprocal arrangements or being ostracised. This actively discourages landholders from adopting non-lethal practices and instils fear of social conflict or reprisals.

The socio-cultural pressures identified accord with the work of other researchers. For example, Kollmuss and Agyeman (2002) found that cultural norms play an important role in shaping individuals' behavior. Treves and Bruskotter (2014) found that the acceptability of lethal control in the US is strongly influenced by peer group norms, as well as government sanctioned killing of predators. Likewise, McManus et al. (2015) found that South African farmers who persisted with carnivore hunting despite the availability of effective non-lethal methods were likely driven more by cultural norms and satisfaction rather than economics.

Socio-cultural norms relating to carnivore persecution can be reinforced by governing institutions. This can lead to a 'lock in' of traditional or past behaviours, making it difficult for individuals or groups to alter their behaviours without negative social, political, or economic consequences thus perpetuating a continued cycle of conflict (Cumming 2018). Conflict occurs not just between producers and wildlife but also within farming communities, as evident from the interviews.

A surprising finding from this study was the intensity of social conflict directed towards innovative producers due to their stance not to kill large carnivores. This raises the question; why is there so much acrimony directed towards innovative producers? Zimmermann et al. (2020) found that deep rooted conflicts over wildlife can become so intertwined with the identities of stakeholders and a community that it can spill over into clashing values and beliefs, as well as blame and hostility. A deeper understanding of such issues requires an explicit account of values, social norms and cultural dispositions among stakeholders, and how these frame global sustainability challenges (Stratford and Davidson 2002a). In doing so, this research contributes towards a greater understanding of how social norms and culture can enable or constrain local coexistence efforts.

Institutional barriers

Formal institutions, including government, the livestock industry as well as non-government organisations (NGOs), create the 'rules of the game'. Institutions shape regulations, policies and incentives upon which systems are designed, organised and governed (O'Brien 2018). This in turn influences norms, conventions and ways of doing things that structure human interactions and activity (North 2005). Institutions either cement the systems and structures of existing regimes or challenge them.

Historically, in both South Africa (Nattrass et al. 2020) and the US (Berger 2006; Bergstrom et al. 2014; Bhattacharyya and Slocombe 2017; Slagle et al. 2017; Stone et al. 2017), the approach to carnivore management has focused on the control of animals to meet human needs (Bekoff and Pierce 2017). 'Control' became synonymous with killing carnivores and was institutionalised by government policy, information and resources (Bekoff and Pierce 2017). In South Africa, financial support from government to kill carnivores was reduced from the 1980s (Nattrass et al. 2020). However, the South African government continues to issue permits for lethal options such as gin-traps and hunting, thus reinforcing this social norm.

In the US, the lethal control of wildlife became institutionalised in 1915 when Congress first approved funds for the lethal control of carnivores (Rashford et al. 2008). More than a century later, Wildlife Services, the government agency tasked with managing wildlife is still heavily criticised for an overreliance on lethal methods (Bergstrom et al. 2014; Bergstrom 2017). Carnivore management is highly politicised with decisions driven by politics rather than science, particularly in the western US (Bergstrom et al. 2014).

A tradition of lethal carnivore control, combined with political power and economic incentives, has resulted in intensified livestock-carnivore conflict in the US (Macon 2020). Analysis of the effect of liberalisation of wolf control in the western US, indicates that polices increase both legal and illegal killing of wolves (Santiago-Ávila et al. 2020; Treves et al. 2021). Montana and Idaho permit the use of traps, snares, hunting hounds, callers, and night hunting on private lands with artificial lights and night vision scopes (IDFG 2021; Montana Legislature, 2021). Integration of preventive innovations in Montana (Young et al. 2019; Boronyak et al. 2020) has been undermined by recent legislature (Montana Legislature, 2021). Senate Bill 314 intends to reduce the wolf population to 15 breeding pairs, equivalent to an 85% reduction of the state's estimated grey wolf population (Montana Legislature, 2021). In the same year, the Governor of Idaho signed Senate Bill 1211 which authorises unregulated and unlimited killing of wolves (Idaho Legislature 2021). This shoring up of political support panders to prejudices, rather than

drawing on evidence-based environmental policy. Ultimately, these policies feed a vicious cycle of subsidy, dependency, and political expediency.

Geels (2011) argues that many existing and often unsustainable systems are stabilised through various 'lock-in' mechanisms such as institutional commitments, power dynamics, economic incentives, shared beliefs and discourses, and political lobbying by incumbents that stabilise existing socio-technical regimes. Formal institutions are part of the dominant regime and can either ignore or actively suppress the emergence of niches of innovation (Darnhofer 2015).

The Multi-Layer Perspective of Socio Technical Transitions Geels and Schot (2007) provides valuable insight into the challenges in establishing niche innovations in an existing regime. In the Multi-Layer Perspective, transitions are dynamic processes that result from interactions across three analytical levels. The first level is the 'niche' that is radical innovation created by actors at the local level. For example, the invention of a new technology (i.e., a visual predator deterrent) (Geels 2011; Darnhofer 2015). The second level is the socio-technical regime, established practices and associated rules that stabilise existing systems, (e.g., the agri-industrial system). The third level is the socio-technical landscape that designates long-term trends such as political ideologies, societal values, globalisation, and disruptors such as climate change or biodiversity loss (Geels 2011; Darnhofer 2015). This Multi-Layer Perspective framework enables an understanding of how preventive innovations emerge and how they can replace, transform or reconfigure existing systems to create more sustainable agriculture (Geels 2011).

Environmental and animal protection NGOs have become powerful actors that have challenged the current agri-industrial regime. Elzen et al. (2011) articulated how system innovation can be driven by normative concerns, such as animal welfare or sustainability. Lobbying by special-interest groups exerts normative pressure on existing regimes to change. In the US, both environmental and animal protection NGOs have strongly opposed lethal carnivore control. These stakeholders have been instrumental in lobbying for change. Their efforts have helped to overcome institutional barriers that block adoption of preventive innovations. These actors have also mobilised support and legitimised and secured resources to support producers to adopt preventive innovations (Darnhofer 2015; Young et al. 2019).

Economic barriers

Livestock predation causes direct and indirect economic losses and is one of the biggest drivers of carnivore persecution (Carter and Linnell 2016a; Macon 2020). Livestock producers have limited economic incentives to conserve wildlife because conservation is a public good that can negatively affect their livelihoods. Producers articulated how the potentially higher upfront and on-going cost to implement preventive innovations created a financial barrier to adoption. Financial barriers to adoption appeared to operate in different spheres across the two countries. In South Africa, financial barriers seemed more prominent in the practical sphere as the costs of preventive innovations are borne by individual producers, and losses to carnivores are not covered by a compensation program. Whereas in the US, financial barriers were more evident in the political sphere as the lethal control of carnivores is often subsidised by government and industry, and livestock losses may be partially or fully covered by compensation programs (Macon 2020).

In South Africa, economics is often used as an argument against adopting preventive innovations due to the perception of higher upfront costs and potential requirement for additional labour (McManus et al. 2015). In general, when sustainable agricultural practices are perceived as increasing the demand for labor, farmers perceive this as disadvantageous because labor is often scarce or expensive (Pannell et al. 2006; Rodriguez et al. 2009). Furthermore, the hiring of additional labor to mitigate predation may be more costly than predation losses. These comparative costs disincentivise investment in preventive innovations (Macon 2020). Yet the costs of lethal control do not appear to be perceived in the same way. Indeed, conventional producers in South Africa are making substantial investments in lethal carnivore control by purchasing purpose-built vehicles or hiring helicopters to carry out lethal control. Such investments are not guaranteed to reduce predation and significantly outweigh the cost of non-lethal options, such as livestock guardian dogs, that can be more effective than lethal control, and provide sustained protection of livestock (van Eeden et al. 2018b).

From the interviews it appeared that innovative producers who adopted preventive innovations reaped financial benefits from less livestock injury and loss to carnivores, as well as overall improved heard health and weight gain. In a South African study, McManus et al. (2015) found that over a two-year period the use of non-lethal tools and options (e.g., livestock guardian dogs and alpacas and/or livestock protection collars) reduced the mean cost of predation by 73 per cent from US$ 20.11 to US$ 5.49 per head of livestock. Another South African study conducted between 2005 and 2011 showed that 97 livestock-guarding dogs working across 94 farms reduced livestock predation by 91 per cent resulting in mean annual financial savings of US$ 3,189 per farm (Rust et al. 2013). A key pathway to coexistence with large carnivores is research partnerships with producers to understand the costs and benefits of preventive innovations (Boronyak et al. 2021).

In the US, economic barriers were evident in the political sphere. Ranchers can access financial support from state and local governments to undertake lethal control of carnivores (Macon 2020). For example, the Idaho Wolf Depredation Control Board recently secured an additional US$392,000 in funding, which combined with other sources equates to over 1 million in funding for activities associated with lethal means of wolf control (Ridler, 2022; Idaho Legislature 2022). Subsidising the cost of carnivore control is an economic distortion that creates financial dependency on the government. These subsidies are an inefficient use of public funds and impede the uptake of preventive innovations.

Compensation programs that reimburse the direct economic loss associated with carnivores killing livestock are politically popular in the US despite a lack of evidence that they increase producer tolerance for carnivores (Naughton-Treves et al. 2003). Compensation schemes can also lead to perverse policy outcomes by creating a disincentive (moral hazard) to adopt new or improved livestock management practices (Nyhus et al. 2003). These barriers act to maintain the structure and operation of existing systems. They reinforce a lethal lock-in or conflict paradigm with large carnivores.

Transformations in the personal sphere

Systems theory suggests that transformations in the personal sphere create deep change because changes have the potential to shape systems, structures, institutions and culture in the political sphere (O'Brien 2018). In turn, changes in the political sphere signal actions, practices, technologies, and solutions in the practical sphere (O'Brien and Sygna 2013; O'Brien 2018; Gosnell et al. 2019).

A growing number of livestock producers from South Africa and the US had overcome the myriad barriers and were operating successful livestock enterprises in coexistence with large carnivores. Coexistence has a strong relational dimension encompassing how people relate to and live alongside wildlife in peaceful and mutually beneficial ways (Marchini et al. 2019). It appears that worldviews, values and priorities distinguish innovative producers from conventional producers who resort to lethal methods. These differences in the personal sphere have been powerful enough to transcend barriers in the practical and political spheres.

Worldviews influence how individuals understand and interact with the world around them, thus shaping human relationships with the natural world (Schlitz et al. 2010). Worldviews shape how individuals perceive ecological challenges, as well as their willingness to take action, and lend political support for measures to address challenges (Hedlund-de Witt 2012; Partelow and Winkler 2016). Hedlund-de Witt (2012) articulates worldviews as 'ecocentric' or 'anthropocentric'. An ecocentric worldview sees humans as part of and dependent on intact ecosystems and acknowledges the intrinsic value of nature. In contrast, an anthropocentric worldview considers an ecological system based on its utility for humans (instrumental value), and the provision of goods and services to human society (Hedlund-de Witt 2012). Shifts in worldview are possible at the scale of individuals and societies (Schlitz et al. 2010). There is a growing recognition of the need to shift our culture from an anthropocentric (human domination over nature) towards an ecocentric (connection with nature) worldview (Hedlund-de Witt 2012).

Analysis of the interview data indicated five key differences between innovative and conventional producers. First, innovative producers had a more expansive or holistic worldview. This worldview acknowledges human connection to nature and the value of carnivores in the landscape. In contrast, conventional producers had an anthropocentric worldview, and saw themselves as separate from and dominant over nature. They deemed it acceptable to kill carnivores that they perceived to be damaging their livestock and livelihoods.

Some of the innovative producers had experienced a fundamental shift in their worldview that led to long-lasting changes in their sense of self, and their relationship with nature. These shifts shaped subsequent actions. For example, some producers initially followed the conventional way of thinking and had implemented lethal methods. However, at some point, they had a realisation that lethal control was not aligned with their values and they no longer found those methods acceptable.

The second distinguishing feature of innovative producers was that they appeared to have different priorities to conventional producers. Innovative producers prioritised long-term ecological health over short-term economic gain. This may have led to a greater consideration of how business decisions would impact the entire social-ecological system. Innovative

producers acknowledged the presence of large carnivores as a critical factor in landscape health and resilience and processes that underpin agricultural production and profitability, as well as connections and dependencies within ecosystems. There was a recognition of the tension in values between agricultural productivity and the persistence of carnivores, but also an acknowledgement that a balance could be achieved without eradicating carnivores.

Thirdly, innovative producers who transitioned away from lethal means towards coexistence displayed a capacity for self-reflection. Self-reflexivity is the ability to step back and become more aware of thoughts, values and behaviours (Schlitz et al. 2010). For example, a producer from South Africa recalled seeing a porcupine caught in a leg hold trap and considered the suffering inflicted on that animal. They chose to stop using traps as this intentional harm no longer aligned with their values. Capacity for self-reflection is thought to stimulate an expanded consciousness and worldview transformation (Schlitz et al. 2010).

Coexistence requires self-reflexivity, empathy, social consciousness beyond ourselves, and extension of the 'circle of compassion' towards non-human communites such as ecosystems and wildlife (Boronyak et al. 2020; Ives et al. 2020). Schlitz et al. (2010 p21) defines social consciousness "*as conscious awareness of being part of an interrelated community of others.*" Social consciousness inspires a desire to actively engage in improving the wellbeing of others and the world. This may manifest as positive values such as compassion, gratitude, peace or forgiveness of others. Social consciousness is one of the most critical elements of transformation because it centres around an awareness of the impact that our actions and behaviours have on other people, species and the planet. The ability of individual actors to transcend the existing lethal control paradigm and cultivate a 'coexistence consciousness' can create profound and lasting transformational change.

Fourth, innovative producers tap into a supportive network of wildlife protection, environmental NGOs, ecologists and other producers for knowledge and support. This support network is crucial to buffer the intense socio-cultural, institutional and economic pressure to conform to the norm of lethal control. It can be extremely difficult when individuals feel they are alone, have no support, or face adversarial pressure from their peers or wider industry for trying alternative approaches. Our evolutionary programming signals that it is dangerous to not be liked as this could lead to rejection and the loss of safety of the group (Short 2005).

Relationships formed between different and often polarised stakeholders can be effective in the development of social capital (networks, support and knowledge sharing). Social capital is the ability to make links with others that may have different views, particularly across communities (Pretty and Smith 2004). Pretty and Ward (2001) identified four aspects of social capital: (1) relations of trust; (2) reciprocity and exchanges; (3) common rules, norms, and sanctions; and (4) connectedness in networks and groups. Social capital is critical for the spread of ideas and concepts that forms an inevitable part of any transformation process (Callicott et al. 2000; Pretty and Smith 2004).

Fifth and finally, innovative producers appeared to be more open to new ways of thinking and scientific information even if it challenges their lived experiences. Innovative producers in this study appeared to be more open to new ideas, and research on the trophic role of carnivores, carnivore ecology, carnivore behaviour (especially when hunting), and the significant role of attractants and deterrents in influencing predation risk (Terborgh and Estes 2010). Innovative

producers took the time to observe wildlife and tried to make sense of the complex biological interactions on their farms. These producers used information and their observations to inform their approach to animal husbandry and selection of tools and practices to reduce predation.

6.5 Conclusions

Preventive non-lethal innovations provide a critical pathway towards achieving conservation goals, good animal welfare and human-wildlife coexistence (Stone et al. 2017; Boronyak et al. 2020; Santiago-Ávila and Lynn 2020). This chapter identified the barriers that prevent the widescale adoption of preventive innovations, and classified barriers across three spheres - practical, political and personal. Within the political sphere, significant barriers to transformational change include socio-cultural pressures, inertia within institutions and economic structures that incentivise lethal control. Institutional structures and policies result in a 'lock-in trap' to lethal carnivore control which, for many producers, impedes adoption of preventive innovations. The adoption of preventive innovations is necessary to avoid a 'lock in' to an unsustainable path that undermines ecological function and resilience, one that contributes to biodiversity loss and species extinction.

An encouraging finding is that despite the barriers in the political sphere, a growing number of livestock producers have successfully adopted a range of preventive innovations. They are practising coexistence, making them leaders in sustainable agriculture, putting them 'ahead of the herd'. These innovative producers appeared to possess worldviews, values and priorities that set them apart from conventional producers who favoured lethal carnivore control. Identifying barriers to coexistence and understanding how individual producers have overcome these barriers, are critical gaps that this Chapter has intended to fulfil. The findings suggest that increasing adoption requires capitalising on the benefits of non-lethal innovations and overcoming barriers—particularly those of a political nature.

Chapter 7: Unlocking lethal dingo management in Australia

In chapter 7, I address sub question 3 through an in-depth examination of the barriers to coexistence in the Australian context with the dingo. The chapter highlights that the most significant barrier in this context are political in nature a finding that aligns to chapter 6. The Australian case study was always intended to be informed by the US and South African research, with a view to seeking to apply lessons learned internationally to an Australian context through a case study of dingoes. This chapter has been written in the form of a research paper for submission to a peer-reviewed journal.

Abstract

Preventive non-lethal innovations form a critical pathway towards human-carnivore coexistence. In the US and South Africa, the adoption of preventive innovations is impeded by factors in the political sphere such as socio-cultural contexts, institutions, and economic incentives. Twenty-one in-depth interviews were conducted with Australian graziers, researchers, and conservation and government representatives to firstly, identify the barriers to the uptake of preventive innovations in livestock grazing in Australia. Secondly, compare the barriers in relation to the four characterises of lock in traps Haider et al. (2017) (i.e., self-reinforcement, persistence and path dependency) to assess how they constrain human-dingo coexistence. Thirdly, to explore transformations in the personal sphere that have enabled innovative Australian producers to move from conflict to coexistence with dingoes.

7.1 Introduction

Coexistence with wildlife is increasingly being advocated as an important way to reduce threats to biodiversity as it advocates tools and practices to mitigate the intentional killing of wildlife thereby improving welfare and conservation outcomes (Boronyak et al. 2021; Schurch et al. 2021). Coexistence is a behavioural state in which individual species live together in the same landscape at the same time and interact in mutually beneficial or reciprocal ways (Carter and Linnell 2016a).

Human-carnivore coexistence in agricultural landscapes largely focusses on preventive innovations that deter carnivores from production landscapes, guard and enclose livestock and increase the resilience of landscapes and domesticated livestock (Johnson and Wallach 2016; Smith et al. 2020; Boronyak et al. 2021). These preventive innovations serve as promising alternatives to lethal carnivore control. They safeguard domestic livestock and large carnivores from harm, thus contributing to more ecologically sustainable animal-based agriculture. The adoption of preventive innovations is occurring in niches across several countries, enabled by transformations in producers' worldviews, beliefs, and priorities. However, adoption is far from being 'mainstreamed'.

In Australia, preventive non-lethal innovations Boronyak et al. (2020) includes livestock guardian animals (van Bommel and Johnson 2014; Johnson and Wallach 2016; Smith et al. 2020), aversive deterrents (Smith et al. 2020), and the removal of attractants such as carcasses (Purcell 2010). These tools and practices can shift the focus from controlling dingoes to

controlling dingo impacts (Brink et al. 2019). However, implementation of coexistence tools and practices is hampered by barriers across Australia.

Australia is endowed with rich biological heritage with a high species endemism (Chapman 2009), yet the resilience of ecosystems is being degraded from a range of causes that include climate change (Steffen et al. 2009), land clearing (Cocklin and Dibden 2009) and loss of biodiversity (Woinarski et al. 2015). Biodiversity loss has, in turn, negative consequences for agriculture, society and the Australian economy that is dependent on commodity exports (Cocklin and Dibden 2009). These sustainability challenges arise from the dynamic interplay of diverse social–ecological factors (Abson et al. 2017). A deeper understanding of complex systems is important to prevent processes that lead to 'lock-in', or 'trap situations' which in the long-run can lead to unsustainable trajectories such as biodiversity, ecosystem degradation and livelihood impoverishment (Boonstra and De Boer 2014).

Lock-in traps arise from complex social-ecological interactions in which structures, systems and the behaviour of individuals reinforces unsustainable choices. Lock-in traps exhibit characteristics of persistence, undesirability, and self-reinforcement ((Haider et al. 2017). Lock in traps are thought to emerge from past decisions and events and are reinforced by path dependencies (Boonstra and De Boer 2014; Haider et al. 2017). Abson et al. (2017 p35) argue that "*much of human action is path dependent, building on the way things have been done previously and relying on established, often institutionalised, knowledge*." Smith et al. (2020) identified path dependencies as an important factor to explain how wildlife management in Australia became locked into a paradigm of lethal wildlife control especially in relation to the dingo. Lock-in traps pervade Australian agriculture and impede systemic change towards improving its environmental sustainability through the integration of agro-ecological principles into commercial production systems (FAO 2018; Iles 2021). It is imperative to facilitate transformation in the way we relate to and govern Social-Ecological Systems (Meadows 1999).

The case of dingo management in Australia is used to explore how factors in the personal, political and practical spheres constrain or enable adoption of preventive non-lethal tools and practices in social-ecological systems. The dingo, Australia's largest mammalian carnivore, has been persecuted for farming since European settlement over 200 years ago. Thus, dingo management in Australia is an important case to explore human-wildlife coexistence (Smith et al. 2019b).

and is perceived differently across Australia as an apex predator, icon, agricultural pest, and spiritual totem for Indigenous Australians (Letnic et al. 2009b; Smith and Litchfield 2009; Fleming et al. 2014; Smith et al. 2019b). These narratives influence human interaction with dingoes.

As apex predators, dingoes play a functional role in maintaining ecosystem processes and therefore warrant protection (Glen et al. 2007; Letnic et al. 2012). Studies show that dingoes reduce the density or change the behaviour of introduced meso-predators via trophic regulation, thereby assisting the survival of smaller native species (Letnic et al. 2009a; Wallach et al. 2010; Letnic et al. 2012). Dingoes can also regulate the abundance and movement of prey species, which in turn benefits plant communities and grazing industries (Letnic et al. 2009b; Wallach et al. 2010; Prowse et al. 2015).

Dingoes are of cultural, social, and spiritual significance to a great many Australians; most significantly Indigenous Australians who hold kinship ties and traditional knowledge about dingoes, other native animals, and the Australian landscape (Rose 2000; Smith and Litchfield 2009). Although the intrinsic, spiritual and ecological value of dingoes is recognised it appears insufficient to overcome the dominant paradigm that narrows the perception of dingoes to 'agricultural pests'.

Livestock can be vulnerable to dingo predation, particularly sheep and calves. The perception of dingoes as a threat is deeply embedded in the Australian psyche and culture, which has resulted in the desire to eradicate dingoes using lethal control (shooting, trapping, and poisoning), primarily to mitigate their impacts on agriculture (Allen and West 2013; Fleming et al. 2014; Campbell et al. 2019).

Coexistence between humans and dingoes has remained elusive because it needs a fundamental transformation in our relationships to and interactions with nature. Meadows Leverage Point Framework (1999) and its iterations O'Brien (2018) have been used to identify interventions that foster human–nature connections (Riechers et al. 2021). I draw on O'Brien (2018) transformational change framework to understand how to catalyse fundamental change towards human-dingo coexistence across three spheres. A key finding of the previous Chapter is that transformational change can be impeded by factors in the political sphere such as social contexts, institutions, and economic incentives.

This chapter explores the barriers to adoption of preventive innovations in extensive livestock production across Australia by drawing upon in-depth interviews with graziers, researchers, and conservation and government representatives. This research aims to, firstly, identify the barriers to the uptake of preventive innovations in livestock grazing in Australia across the three spheres (practical, political and personal). Secondly, compare the barriers in relation to the four characteristics of lock in traps identified by Haider et al. (2017) (i.e., self-reinforcement, persistence and path dependency). Thirdly, explore transformations in the personal sphere that have enabled innovative Australian producers to move from conflict to coexistence with dingoes.

7.2 Methods

In total, twenty-one in-depth semi-structured interviews were conducted with stakeholders in the Australian extensive livestock sector. Interviewees were identified through purposive sampling to deliberately select candidates who met the criteria of having relevant experience or knowledge relating to carnivores or agriculture and willingness to participate in the research (Etikan et al. 2016). A snowball sampling method enabled the identification and recruitment of candidates across a broad spectrum of views relating to human-dingo conflict and coexistence in production landscapes. Interviewees included: livestock producers (thirteen), a livestock industry representative and a representative of the Centre for Invasive Species Solutions (CISS) (two). Government agencies that oversee wildlife management and/or agricultural interests from New South Wales, Victoria and South Australia (three), staff from environmental and animal protection NGOs (two), and a researcher specialising in preventive innovations (one).

Within the sample of Australian livestock producers, eight producers (seven cattle and one sheep producer) did not kill dingoes that inhabited or moved through their property (herein innovative producers). The remaining five producers, all sheep producers, relied primarily on lethal management to reduce dingo predation (herein conventional producers). Two of the conventional producers participated in a 'pest animal' or 'wild dog group', that is a volunteer group of landholders that primarily use lethal control of dingoes, wild dogs and hybrid offspring.

Interviews lasted from one to three hours and were conducted primarily over the telephone. Only two interviews were conducted in person due to travel restrictions imposed because of the COVID-19 pandemic. Interviews commenced with participants introducing themselves and giving an overview of their livestock operation or role in government or NGO, and their interactions with dingoes. Livestock producers were questioned about the various ways they mitigate dingo predation (using lethal or non-lethal tools and methods or a mix of both), the barriers and constraints to adopting preventive non-lethal innovations, as well as the processes, events and conditions which precipitated, facilitated, and enabled adoption to occur (or not). With the participants' consent all interviews were audio recorded and transcribed verbatim. Interviews were analysed thematically whereby repeated coding, sorting, and categorising were conducted using MAXQDA software (VERBI GmbH version 18.2.0) (Saldaña 2009). Exemplar quotes were selected to shed light on recurring themes relating to barriers and how they were overcome in the adoption of preventive non-lethal practices.

7.3 Results

Practices to mitigate dingo predation

Lethal means to reduce predation risk (e.g., shooting, trapping and distributing poisoned meat baits), were used by all six sheep producers except one who did not use lethal control but instead used a deterrent called a Foxlight. Government representatives reported the use of helicopters to facilitate regional aerial baiting to poison canids such as dingoes, feral dogs and foxes. Two sheep producers used a mixed strategy that consisted of preventive non-lethal innovations, (e.g, livestock guardian dogs and donkeys), in conjunction with lethal control (i.e., trapping and/or shooting backed up by regional poison baiting).

Cattle producers utilised a mix of lethal and non-lethal approaches or abstained from any action due to the greater resilience of cattle to dingo predation. Five cattle graziers practiced a 'no kill' approach and allowed dingoes to form social groups and maintain territories. Producers that utilised guardian dogs or identified as organic producers generally refrained from baiting to avoid killing their working dogs or to maintain organic certification. The wide range of approaches to manage real and perceived dingo predation reflects the complexity and heterogeneity of strategies in extensive livestock production systems. The results also revealed interesting insights into the socio-cultural norms influencing human-dingo interactions.

Barriers in the practical sphere

Barriers in the practical sphere include lack of landholder capacity (knowledge, skills, and experience) to adopt preventive innovations. Several conventional producers reported difficulties implementing some non-lethal techniques. For example, management difficulties on large landholdings were frequently cited as limiting options for adoption of non-lethal practices such as livestock guardian dogs. Landholders may be unable to easily locate and feed guardian dogs, although new GPS tracking technology could overcome those issues. The size and remoteness of many farming operations makes installation, repair, and replacement of equipment very difficult, time consuming and expensive. Interviewees reported that these practical barriers to the use of technology in extensive grazing in Australia, constrained implementation of some preventive non-lethal innovations. Analysis showed that political and personal spheres appeared to exert greater influence on decisions relating to dingo interactions than the practical sphere. This also aligns O'Brien's grouping of Meadows (1999) Leverage Point Framework across the three spheres from shallow intervention (personal sphere) to more significant interventions in the political and personal spheres. Accordingly, the results presented here focus on the barriers in the political and personal spheres.

Barriers in the political sphere

The following section identifies the most influential barriers in the political sphere including socio-cultural, institutional (laws, polices, information and capacity building) and economic factors that constrained adoption of preventive innovations. The barriers are illustrated by a diversity of stakeholder quotes. I explore how and why these barriers impede the adoption of preventive innovations, and systemic change towards coexistence.

Socio-cultural barriers

A key barrier to the adoption of preventive innovations is the intense socio-cultural pressure on producers to conform to social norms around lethal dingo control. Pressure to conform to accepted social norms occurs over time from neighbours or peers (i.e., from the bottom-up). These norms are reinforced by top-down pressure from industry and government that have, over time, normalised lethal control.

Social pressure to use lethal dingo control was experienced by all of the innovative producers, and took forms such as name-calling, verbal abuse or feelings of being 'under attack' in their communities. These socio-cultural factors appeared to be important in creating a self-reinforcing system of lethal dingo control.

> *"You're a greenie bunny hugger and a tree hugger that sort of thing is fairly common. Any time you do anything different you are likely to get an attack. In this case, if they are getting animals [livestock] taken out and I am not then I must be harbouring the pest.*"
>
> Innovative cattle and chicken producer, New South Wales

> *"There is enormous pressure in the neighbourhood. We were mocked and abused. It can get extremely vehement, and it was very, very tough…… where we were almost considered the downfall of the neighbourhood.*"
>
> Innovative cattle producer, South Australia

"My immediate neighbours are pretty good, but I have had a lot of abuse from other areas."

<div align="right">Non-lethal producer, Queensland</div>

Conflicts over dingoes in grazing communities can become extreme and escalate to the point where producers and their families are ostracised from the community simply for refraining from lethal dingo control. This raises an important consideration as to why the reaction of conventional producers to innovative producers is so extreme.

"The pressure is definitely there. I mean, we're a bit ostracised from the community but it's hard to ostracise someone that doesn't really care what people think to be perfectly blunt."

<div align="right">Innovative cattle producer, Western Australia</div>

"The biggest negative is social interactions with other people because some people are so incensed that I don't do what's always been done [lethal control] *and some people have stopped talking to my wife."*

<div align="right">Innovative cattle producer, Queensland</div>

Social pressure can be subversive when people are silenced because they have a view that differs from local social norms that favour lethal dingo control. Producers who spoke out in opposition to lethal control or used non-lethal control practices, risked being 'visible'. Due to the intensity of the socio-cultural pressure, innovative producers noted that speaking publicly on this issue may make them a target of social conflict, which was expressed as an embodiment of the risks (i.e., 'going out on a limb' or 'sticking head up'). Given the potential to become a target, innovative producers needed to be resilient in the face of negative feedback to move beyond the norm.

"*It takes a bit of backbone to be able to go out on a limb and make these changes* [adopt non-lethal] *because there are some fairly deeply ingrained views on predators in a lot of regions. So, it takes guts to buck the trend, and try something new."*

<div align="right">Conservation NGO representative 1</div>

"There are a few people out there starting to do it [use non-lethal practices] *but most of them are definitely not prepared to stick their head up at this point because they're going to get a lot of negative impact socially from other people in the area."*

<div align="right">Innovative cattle producer, Queensland</div>

Conventional producers exert pressure on their neighbours to implement lethal control because dingoes are mobile and can have a large territory. There is a strong narrative that producers must do their part to combat 'pest' species. This is a species that can have a negative impact on livestock and livelihoods. However, lethal methods such as baiting can be deadly to both livestock guardian and herding dogs, which impacts innovative producers.

"People with Maremma guardian dogs, for example don't like using poison, and there are still issues with organic certification….Some people just have an issue with anyone that's accidentally poisoned their kelpie, that it's not visually pleasant, watching a dog or even a fox or canid dying from ingesting a bait…some people have a moral objection to it".

State government representative, Victoria

The intense social pressure to engage in lethal dingo control may arise because preventive non-lethal tools and practices differ from the prevailing current social norms of the local community. It appears that conventional producers prefer to use lethal methods because that engenders a sense of control over the 'problem' of predation. There may be a sense of satisfaction to 'get' the perpetrator. They believe that lethal control provides a means to resolve the problem of livestock predation, although it often provides only a temporary 'fix'. An interesting cultural phenomenon is the triumphant display of dead dingoes from a fence or tree like trophies to perhaps gain recognition and appreciation from peers for assisting agricultural communities to deal with the challenge of dingoes (Hytten 2009).

"The most popular and favoured control method is leg-hold trapping…The reason it's favoured among farmers in particular, and this is not saying that they do it, but the reason they like it is, you catch a dog you can hold a dog up by its hind legs and say, here it is, I've got the bastard"

State government representative, Victoria

"You can't hang a dog that's been baited on the fence like you can when it's been trapped… I call it the 'cricket score mentality', it's all about how many dead dogs we got rather than how few sheep were attacked."

Representative of the Centre for Invasive Species Solutions

Culture in grazing industries appears to be heavily influenced by past traditions. Adherence to traditions may create path dependencies that are difficult to deviate from. The social pressure to conform to 'traditional ways' or the lethal status quo likely arises from the local community. Traditions are reinforced by the livestock industry, creating a reinforcing feedback loop. The traditional values and 'in-built conservatism' in rural communities may contribute to a reluctance to try new tools and approaches, especially when those approaches deviate from practices that have persisted for more than two hundred years.

"There is resistance to change, because for generations, things [lethal control] *that we've been doing for more than a hundred years, is still going on. Because that's how people are taught to do things. And there's sort of this status quo situation."*

Conservation NGO representative 1

"I think it's a case of actually not looking at what's really happening [on the ground] *just having a theory or a long-held tradition of doing what they do and not thinking about a better way forward. And I love the thought that tradition is peer pressure from dead people."*

Innovative cattle producer, Queensland

Institutional barriers

As culture and institutions have co-evolved, the prevailing culture of lethal dingo control has influenced institutional priorities, policies, information and incentives of both government and the livestock industry. Key actors with political power, such as government and the livestock industry, widely support lethal management of dingoes.

As negative perceptions of dingoes are prevalent in rural communities, this can result in a culture that is largely focused on the eradication of dingoes. Moreover, lethal dingo control is conducted at the local and regional level often by local government representatives that are drawn from and share the values of conservative rural communities. Thus, the deeply entrenched views that dingoes are a menace to livestock industries and need to be 'controlled' with lethal approaches, are reinforced.

> *"The issue is that the culture is to kill all the dingoes and the government's actions reflect that."*
>
> Innovative cattle producer, Western Australia

> *"Everybody out here's hated dingoes forever because this whole district used to be sheep, so we have a very entrenched view about dingoes, that dingoes are the worst thing ever."*
>
> Innovative Cattle producer, Western Australia

In most states, landholders are compelled by law to control dingoes by designating them a 'declared pest' or 'threat to biosecurity'. For example, in Victoria:

> *"The Victorian wild dog space is that our Catchment and Land Protection Act requires that all land managers control and where possible eradicate established pest species. Wild dogs and dingoes are a declared pest species when they live in certain areas."*
>
> State government representative, Wild Dog Program, Victoria

This 'declared pest' designation creates an impediment to non-lethal ways of interacting with dingoes. As a result, landholders who refrain from lethal control face top-down pressure in the form of formal institutional sanctions. They may be subjected to social pressure such as being threatened with legal action for breaking the law.

> *"I get called names and I am attacked in the media…. There's also been people trying to get our local council to take legal action against me but that didn't work."*
>
> Innovative cattle producer, Queensland

In most Australian states, except Victoria, the management responsibilities for dingoes have devolved to regional-based institutions such as Local Land Services (LLS) in New South Wales, local councils in Queensland, Landscape Boards in South Australia, and Recognised Biosecurity Groups in Western Australia. To create policy and to oversee wild dog groups at a national level, a National Wild Dog Committee was established that comprises industry representatives such as the National Farmers' Federation, Ag Force Queensland, cattlemen's' and graziers' associations, as well as peak industry associations including Australian Wool Innovation (AWI) Limited, Meat and Livestock Australia (MLA) and Wool Producers Australia, as well as state government staff and the Centre for Invasive Species Solutions (https://wilddogplan.org.au/about-the-nwdap/national-committee).

The National Wild Dog Committee developed the initial National Wild Dog Action Plan 2014-2019 that advocates an integrated and coordinated to approach to dingoes, referred to as wild dogs. These organisations, in turn, provide infrastructure (i.e., systems, structures and policies) for local community organisations such as 'wild dog groups', 'pest control groups' or 'biosecurity groups' to carry out regionally coordinated dingo control. Part of this approach is a 'nil tenure' process that aims to reduce conflicts between landholders in relation to wildlife. This reinforces a widely held perception that dingoes or wild dogs belong to government.

> "*They* [wild dogs] *belong to the government, these wild dogs, they're their dogs, not ours*."
>
> Conventional sheep producer, New South Wales

Membership of wild dog groups is drawn from local farming communities that favour lethal options. Hence, there tends to be an unequal representation of producers who prefer non-lethal tools and methods. When lethal control of dingoes becomes the main strategy to reduce predation, it results in a reinforcement of this system, potentially crowding out alternative perspectives, actions and dissenting voices.

> "*The nil tenure management planning process which was kicked off in NSW in 2000 was an approach where taking away the land tenure and the blame for who owned* [wild] *dogs, that was often the case… to get rid of those lists of tenures and to get landholders to sit together and all have a say in the understanding and direction of the issue and then the understanding and the direction of the controls, and realistically that's what the National Wild Dog Action Plan that I now deliver is all about*."
>
> Representative of the Centre for Invasive Species Solutions

> "*Bite back* [wild dog] *groups are formed to try and coordinate baiting to the Spring and Autumn times and to get people to start working in local collectives to manage the dogs in their regions*."
>
> Conventional cattle producers, South Australia

However, not everyone is satisfied with participating in a wild dog group. One sheep producer who used a mixed strategy of shooting and trapping and livestock guardian dogs to protect his sheep refrained from baiting on his property. Although he did not elaborate as to why he was no longer part of a wild dog group, he made evident that there was some conflict within the group resulting in his decision to withdraw.

> "*We sort of tried to be in that* [wild dog group], *but that's a waste of time, too many people have got too many ideas and there's too many 'blues'* [arguments]."
>
> Conventional sheep and cattle producer, Victoria

Nevertheless, there is widescale local and industry support for groups to carry out lethal options, particularly poison baiting and trapping. For example, industry works in partnership with government to create the infrastructure for poisoned baiting. Government agencies work with established pest groups, providing ready-made baits to landholders. This government support creates a path dependency on poison baiting as the primary strategy for mitigating dingo predation on livestock.

> "*We have contracts with five Local Land Services in NSW at the moment. They can provide a service which is both to the people injecting the baits or putting them out or the aircraft that is distributing. Australian Wool Innovation provides freezers and drying racks so you can dry your meat baits and store them in boxes in the freezers ready for your next baiting program*."
>
> Sheep grazing industry representative

> "*Baiting is a strategy, it's one of our tools but we also do wild dog trapping. As the coordinator of the* [pest animal] *group, farmers ring me about how many [baits] they want, and I pass that information on. The baits come to the group ready-made via Local Land Services*."
>
> Conventional sheep producer, New South Wales

This coordinated approach makes it easy for landholders to deal with dingoes in a lethal way. It also pressures landholders into this behaviour by making it appear almost as a civic duty to communities and the environment. For example, cattle producers had experienced pressure from the government and sheep grazing industry to undertake lethal control despite dingoes not significantly affecting their operations.

> "*We deal with those cattle producers, because ideally we like them to do wild dog control even though most of them don't need to, because most of the time their cattle's not being eaten*."
>
> State government representative, Wild Dog Program, Victoria

"There's a fair bit of influence that we have through these community groups. Now people go and join the Rural Fire Service because they see that as a civic duty as they move to the country, but they often don't realise that pest management (whether that's weeds or pest animal management) is equally just as important from a community and an environmental perspective."

Representative of the Centre for Invasive Species Solutions

These systems and structures, involving community members in wild dog groups to deliver coordinated control, make lethal control widespread and institutionally supported. This perpetuates the lethal paradigm, creating and reinforcing an institutional lock-in trap.

"I think, one of the limitations here, is that the programs are so widespread, and supported, that there's just a massive resistance to change. So, it's kind of like the machine is too big, sort of thing, to influence."

Conservation NGO representative 1

This maintenance of the status quo is further reified by institutional rhetoric that if lethal control was not carried out, jobs would be lost by those who are employed in lethal control activities. In Victoria, the management of dingoes is carried out at the state level under the Wild Dog Program, with a hierarchy of roles including Project Manager, Operations Managers, Senior Wild Dog Controllers, and trappers colloquially referred to as 'doggers'. The creation of these formal, bureaucratic roles has the potential to create path dependencies to continue investment in and support for lethal control.

"One of the differences in Victoria is that there are about seventeen or eighteen state government employees who are doggers."

Sheep industry representative

"There's a vested interest by all these people that work in these government programs to have jobs. So, if anybody was to come up with a solution whereas they didn't have to use 1080 poison bait, they wouldn't have jobs."

Innovative sheep producer, New South Wales

Capacity constraints can take the form of a lack of knowledge, skills or experience in a particular area. Many of the producers interviewed said they sourced information about dingoes and mitigating dingo predation from other producers, industry and government. However, it appeared that information and capacity building activities provided by government largely advocate lethal control techniques. For example, two government representatives stated:

"Baiting is a very good technique for large scale control and for very large numbers of dogs, it's really the way to go."

State government representative, Wild Dog Program, Victoria

"We encourage as many dogs get shot as they can, so we are encouraging people to start carrying rifles if you're going out to the paddocks as much as they can particularly if the know a wild dog is in the area."

<div align="right">Government representative, New South Wales</div>

"We have technology that's quite adequate, there are no real shortages in technology in terms of disposing of predators, we're actually (in plain language) quite good at killing things"

<div align="right">Sheep grazing industry representative</div>

In addition, the training offered by government agencies to landholders selectively focuses on lethal control especially poisoning and trapping. It seems that no such training is provided for the array of preventive innovations. This creates an imbalance in the provision of information about the suite of tools and resources available to manage predation risk.

"We've also done a fair bit of trapping training the last few years as well. One level is just for one day trapping training which just gives them the basics of resetting a trap. Professional dog trappers come in and set up trap lines where they can check them and reset them, to get their skills where they can maintain a trap line, bringing down the cost of trapping. We've been doing a three-day wild dog trapping training…trying to get at least a couple of members in each [wild dog] group going through and get the grant to do it."

<div align="right">Government representative, New South Wales</div>

"We'll run days where we have a small group of farmers that are interested in learning how to trap, so we'll demonstrate how you go about trapping. We'll demonstrate the baiting process, why you bait, how you bait, where you bait. We are trying to be more supportive of the guardian animals, particularly Maremmas and Anatolians, just to get a bit of balance, is probably the one thing we fall down on…we don't use Maremmas ourselves, we can only trap, bait, shoot and educate."

<div align="right">State government representative, Wild Dog Program, Victoria</div>

"We're getting people more in tune to where to put baits in relation to dog activity, has been a really strong shift in the way people are doing stuff. We've held a lot of workshops, predator management workshops throughout the country."

<div align="right">Representative of the Centre for Invasive Species Solutions</div>

There is some recognition that information on preventive innovations could be provided to landholders, thus creating more balanced support to adopt alternatives. However, lethal dingo control is sold to landholders as a 'service'. This has over time created an expectation for and reliance on this service ensuring a lethal practice lock-in.

"We really deliver that frontline delivery service to landholders in doing wild dog controls."

<div align="right">Government representative, New South Wales</div>

"The industry messaging on it has turned it into a service that landholders' value and have come to expect. I think there's a real education issue there and as well as people's values, I guess in terms of what's an acceptable suffering for a predator to go through, even if killing is okay."

<div align="right">Conservation NGO representative 1</div>

The lack of support for non-lethal options in Australia creates an institutional barrier to change in the political sphere.

"This lack of institutional support is hampering adoption [of non-lethal methods] *especially when there is much greater support for lethal management using poisoned baits in New South Wales via the government agency Local Land Services or for trapping via the Victorian Government."*

<div align="right">Researcher, Australia</div>

Information barriers

Industry power reinforces the lock-in to lethal control by setting priorities for information dissemination and research funding that limit preventive innovations. The political power of both the grazing industry bodies, such as Meat and Livestock Australia and Australian Wool Innovation, and chemical industries that manufacture the poison used to kill dingoes, stabilises the lethal paradigm. Furthermore, as industry collects producer levies, there is a pool of funding for research and communications which tends to focus on lethal options.

"I think that there's definitely an industry backed research contingent. There's a lot of money that groups like Australian Wool Innovation and others get. So, there is an imbalanced funding. The high power of the wool board they hold the political testicles."

<div align="right">Conservation NGO representative 2</div>

"Meat and Livestock Australia who provide a lot of the money for the Invasive Animal CRC [now Centre for Invasive Species Solutions] *decided the only things they were going to fund from now on was anything that killed predators. They were not interested in non-lethal and as far as I know, that hasn't changed since. I think it has a lot to do with them and all the farmers' organisations, all those really big corporations they basically set the tone for what gets funded."*

<div align="right">Researcher, Australia</div>

The industry messaging appears to purposely devalue dingoes, this is evident in the change of name from dingoes to wild dogs. Lethal control is normalised by devaluing the dingo, referring to it as a 'wild dog' and labelling is an invasive 'pest'.

"The local area we live in, it's had what was called the Dingo Association, now it's the Wild Dog Association and that went right back to the early 1900s".

Conventional sheep producer, Queensland

"The myth that's been deliberately championed by people who are making money out of that myth, the killers, mostly the poison people. The chemical industry that has been the worst part. Those people have put money behind it. It's a marketing exercise to de-value the dingo, because it's a nuisance to the wool industry and what are we devaluing? Something that's totally unique."

Conservation NGO representative 2

Lastly, the media perpetuates a wider social discourse that dingoes are negative and need to be controlled. This media discourse further justifies the continuation of lethal control.

"Whenever there's any article here, television, radio or in print, the bias inevitably towards getting rid of the dingoes and of the opinion that maybe it's a bad idea is never voiced… It's never a balanced story, ever."

Innovative cattle producer, South Australia

Economic barriers

The reinforcement of lethal dingo control occurs when livestock producers lobby for institutional support which is provided in the form of 'pest control'. When industry and government financial support is biased towards lethal options, this creates an economic barrier to the adoption of preventive innovations. There appears to be virtually no institutional support for preventive innovations. Consequently, the costs of adopting preventive innovations are borne by individual landholders.

"Australian Wool Innovation funding has been around 90% on wild dogs and the other 10% on the rest [other native and introduced species]."

Sheep grazing industry representative

"The state government allocates vast majority of its allocated funding is for lethal control, because all the government can do is to control the dogs on crown land."

State government representative, Wild Dog Program, Victoria

"The last couple of years we've been given the test levy funding money, so we've started doing aerial wild dog baiting in all the [wild dog] *group areas in all that accessible country to try and fill in as much as we can - so doing that"*.

State government representative, New South Wales

Government subsidies for lethal dingo control, such as wild dog bounties in South Australia, are provided under the guise of drought relief. A bounty is a financial incentive or reward, offered by a government for an act or service, in this case the killing of unwanted wildlife (Hytten 2009).

"The bounty program is more a measure of a way of giving back to landholders that are being affected by drought conditions and wild dogs… To give them a bit of cash in their pocket that will help them with their cash flow. If they have dogs on their place and they are able to get $120 a dog, then it will help them financially."

State government representative, South Australia

One producer whose farm was located outside of the dingo barrier fence in South Australia said that the bounty would create an incentive to drive around looking for dingoes/wild dogs to shoot.

"That would have incentivised me to go out and make more of an effort. The amount of times I see dogs and I'm just too busy and I think, no I'm just going to drive past and I don't do anything. But $120 you're definitely going to go looking for dogs. In fact, for $120, it's almost worthwhile driving around having a look for them."

Conventional cattle producer, South Australia

In summary, it was evident that innovative producers experienced various forms of socio-cultural pressure to conform. In addition, the combination of capacity building (e.g., information and training) in lethal methods, as well as financial incentives to kill carnivores (e.g., bounty payments and free or subsidized baiting) has led to a deeply ingrained institutionalisation of lethal control. Despite these significant barriers that are largely of a political nature, producers were found who had adopted non-lethal practices. As the next section explores, these producers shared a narrative of their 'transformation journey', detailing how and why they had overcome barriers to tolerate and coexist with dingoes.

Transformation in the personal sphere

Despite the barriers within the personal and political spheres, several livestock producers transcended the lock-in to transform conflict into coexistence. These producers managed to reduce the cost of living alongside dingoes and capitalise on the benefits of their retention in the landscape. Some of the innovative producers had previously been engaged in other professions before taking up full time farming. Hence, they had not been culturally ingrained to hate dingoes. Perhaps, they were more open to positively considering dingoes in the landscape. However, innovative producers also came from multi-generational farming communities. These producers had seemingly transitioned away from a linear way of thinking that viewed dingoes as a problem to be eradicated. Their approach had transformed into a more holistic consideration of the role of dingoes in a diverse, healthy and functioning ecosystem that supports productive livestock grazing. The following section details some of the characteristics in the personal sphere, including world views, values, priorities and identity, that set innovators apart from conventional producers.

Innovative producers that chose to tolerate or coexist with dingoes appeared to have an expansive world view that encompassed holistic thinking about the environment and the long-term implications of their decisions. Innovative producers seemed to possess a strong

conviction that their beliefs, values and actions are right for their farm. This may have enabled them to withstand the intense socio-cultural, institutional and economic pressure in the political sphere. This can be extremely difficult when individuals feel they are alone, have no support or face adversarial pressure from their local community or the grazing industry for trying alternative approaches.

"People have said to me, don't you feel like you've got a responsibility to your neighbours and their stock – and I do, but it's nowhere near the responsibility that I have to the Australian people to manage their land well."

Innovative cattle producer, Western Australia

"What matters is the condition of our country and the condition of our stock and what happens in the long term with regards to sustainability and it's going to be very much part of our social license to operate into the future."

Innovative cattle producer, Queensland

Innovative producers appeared to have different priorities from conventional producers. Some prioritised the rehabilitation of degraded farmland from the clearing of native vegetation and overstocking of livestock. These producers tended to prioritise ecological sustainability over economic or social considerations.

"We try to give them [cattle] *the best life we can, but we're certainly not here to try and maximise our dollars out of cattle and we are trying to rehabilitate the land as best we can with serious attempts to not over-graze and restore the rest of the land that we got and that includes leaving things as a complete ecosystem, and we think the dingo plays a major role in that."*

Innovative cattle producer, South Australia

In contrast, conventional producers appeared to have a reductionist or mechanistic world view that favoured more linear connections between dingo removal and improved farm profit. Intentional and planned killing of dingoes may provide conventional graziers with a sense of control over livestock predation, an external and random event. However, killing carnivores may have no effect on predation risk and in some cases, lethal measures can worsen rates of predation.

"The only way sheep and dogs can exist is with an exclusion fence, they've got to be separated. If you want to run small animals and be viable [in business] *and be sane mentally, wild dogs and small animals do not mix. There is no room."*

Conventional sheep producer, Queensland

"We'd like to eradicate them. I don't know if that's possible"

Conventional sheep producer, New South Wales

> *"We shoot them when we see them. That's how we control them. Whenever you see one you can shoot, you do."*

<div align="right">Conventional cattle producers, South Australia</div>

In contrast, some innovative cattle producers appeared to have a deeper understanding of ecology and had spent time observing and attempting to understand the complex biological interactions on their farm. Some innovative producers refrained from lethal dingo control as they believed that this caused disruption to the social structures of dingo groups, which for various ecological reasons can worsen rates of predation. They also shifted their focus from the costs of dingoes on production towards the role that dingoes play as apex predators in a healthy and functioning landscape. They recognised that these ecological processes underpin biodiversity, productivity and sustainable agriculture.

> *"I see dingoes as crucially important for the long-term maintenance of most sustainability of agriculture but also for biodiversity conservation for making sure our different ecosystems are functioning properly."*

<div align="right">Innovative cattle producer, Queensland</div>

> *"We believe in the pack structure and that the overall system is better off left alone, we firmly believe that."*

<div align="right">Innovative cattle producers, South Australia</div>

> *"Most of the land managers have lived in times of baiting, the only effects they see from dingoes is from disrupted family structures. They don't get to see how it operates when left alone. There are very few people managing land that have actually seen the effects of leaving dingoes alone. So, all the life experience and judgement they're making is made on disrupted family structure."*

<div align="right">Innovative cattle producer, Queensland</div>

Innovative producers shared what could be described as a holistic worldview that recognises interdependencies, rather than an 'us/them' divisive approach. Innovative producers appeared more open to new ideas and scientific information about the ecological role of dingoes and interconnected web of species. They were more likely to use this information to modify and adapt their approaches and priorities based on new ways of thinking.

> *"When you have a holistic understanding of the environment where it's not just about species, it's about all those connections……I mean, there is heaps of research here showing either side of the dingo fence, where having a key predator builds biodiversity. We are still very much focused on the pest, on the problem on the predator rather than saying hold on let's look big picture. It comes back to changing the paradigm."*

<div align="right">Innovative poultry and cattle producer, New South Wales</div>

"Our general philosophy is trying to find a responsible and sustainable way to manage the land. Livestock come secondary to that. We've always sort of entered into this making sure that we don't assume that livestock management is even set in concrete, we set off with that mindset."

Innovative cattle producer, Western Australia

Some innovative producers recognised that dingo persecution is counterproductive to achieving their environmental and business goals. Producers who were successfully coexisting with dingoes tended to believe that dingoes assisted their enterprise by managing the grazing impacts of wild herbivores, as well as supporting rotational grazing.

"Dingoes are essential for rotational grazing, and out here if you really want responsible management, and to be able to rest the country, we need dingoes. I don't think we can recover the landscape without the dingo."

Innovative cattle producer, Western Australia

It appeared that producers who acknowledged the ecological and production benefits of dingoes were more likely to refrain from lethal options. Their perceptions of dingoes informed their actions. This had flow on benefits to their business.

"The time and money that people spend shooting wild dogs or even baiting – we obviously don't do that. We don't have to worry about that, as it's a labour and cost saving."

Innovative cattle producers, South Australia

"We spend zero time and resources seeking to control our dingo population. The financial outcomes we obtain I believe are much better than cattle producers who spend considerable time and resources seeking to persecute dingoes."

Innovative cattle producer, Queensland

In contrast, conventional producers had a strong belief in the efficacy and benefit of lethal options. They chose to spend considerable time and resources implementing lethal control despite the recognition that this could create a void for another dingo to occupy. Consequently, lethal control has become a continuously onerous task.

"We've always got traps set, continuously, because obviously when you remove one dog, it makes room for another one to come in."

Conventional sheep producer, Queensland

Another key factor that differentiated innovative from conventional producers is tolerance for livestock loss (injury and death) that potentially results from encounters with dingoes. As dingoes are not evenly distributed throughout the landscape, exposure to predation risk appears to vary by geography, landscape and livestock type. During the interviews, it was clear that conventional producers of small livestock believed that dingoes and sheep were unable to coexist due to the potential for dingoes to injure or kill domestic livestock. There was

a dichotomy between how sheep and cattle producers perceived and interacted with dingoes. In general, sheep graziers exhibited a lower tolerance for dingoes than cattle producers.

"What we can't accept is predation on our production animals."

<div align="right">Conventional sheep producer, New South Wales</div>

"I doubt very much you could ever have a wild dog living harmoniously with small animals because they are a predator, and they love the chase."

<div align="right">Conventional sheep producer, Queensland</div>

"When this place was running sheep and they would have been literally wiping out every dog on the place because that's the only way you could have sheep."

<div align="right">Conventional cattle producers, South Australia</div>

"This is the difference between the cattle industry and the sheep industry, you cannot have wild dogs and sheep in the same landscape and expect a little or no predation."

<div align="right">Sheep industry representative</div>

When tolerance for losses is low, this creates impediments to considering options and finding compromise between stakeholder groups that hold different values or knowledge of dingoes. When asked about the efficacy of non-lethal options when compared to lethal options, conventional producers tended to dismiss non-lethal tools and approaches. In contrast, innovative producers were comparatively more open, especially in trialling alternative approaches. Many of them had gone down this path. Producers who were driven to try a new tool or approach persisted despite the uncertainty, and lack of guidance and support.

"Talking to all the producers, that's one of the things they mentioned that it was just extremely hard to get started [with livestock guardian dogs], *but of course, that's mostly the same for people who actually did make it through and then persisted and they got there."*

<div align="right">Researcher, Australia</div>

Innovative graziers also exhibited traits that differentiated them from conventional producers. This included confidence, openness, curiosity, persistence and less fear of failure if the strategy failed to mitigate livestock predation.

"You've just got to have the confidence, if you try it and it's working you've got to have the confidence to punch through the social barrier."

<div align="right">Innovative cattle producer, Queensland</div>

"The fortunate thing that I've had that's set me aside from all other farmers, even my own family, is the fact that I don't have the fear of failure. You have an idea, if you don't try it then you have nothing. But you have an idea and it fails then you can work your way around it and say, well, if it's got some merit but it's the practical side of it that needs changing."

<div align="right">Innovative sheep and cattle producer, New South Wales</div>

7.4 Discussion

This chapter elucidates barriers that impede the adoption of preventive non-lethal innovations in Australian agriculture. In the practical sphere, barriers include a lack of capacity (knowledge, skills and experience) to implement preventive innovations, the size and remoteness of extensive grazing enterprises, and lack of interest. For example, the use of livestock guardian dogs is seen as difficult across extensive enterprises. Lack of interest in alternatives to lethal control arose due to the belief in lethal options. Lethal options, such as shooting, poisoning and trapping, are more familiar to producers. Preventive innovations, on the other hand, are perceived as yet to be proven effective, and potentially costing more. Furthermore, non-lethal interventions have been criticised for a lack of experimentally derived evidence of their effectiveness (Eklund et al. 2017). Smith et al. (2020) identified various barriers to non-lethal management of dingoes in Australia, including perceived higher cost and lower efficacy of non-lethal compared to lethal control, the size and remoteness of farming operations, lack of government support for non-lethal practices, as well as social stigma. Most of these barriers fall in the practical sphere that on its own has shallow transformation potential (Meadows 1999; O'Brien 2018). However, interventions at shallow leverage points should not be dismissed altogether. There is the potential for ripple effects Everard et al. (2016) that create an enabling environment, building and supporting niches of innovation (Schot and Geels 2007; Ives and Fischer 2017).

Transformation towards coexistence with dingoes in extensive grazing is significantly impeded by barriers in the political sphere. These barriers relate to socio-cultural, institutional, and economic factors. Iles (2021) identified a similar array of political economy and socio-ecological lock-ins that inhibit a transition to agroecology in Australia. As Cocklin and Dibden (2009 p 4) point out, producers' decisions are not made in isolation as farmers are "*influenced by government policies, which have until recently been unsympathetic to environmental concerns, and more recently have been largely determined by what might be called the tyranny of the market*". In order to remain profitable, farmers are often forced to clear more native vegetation or overstock their paddocks, despite an awareness that this contributes to land degradation.

The influence of the political sphere is not limited to agriculture but also applies to sustainability transformations more broadly. Patterson et al. (2017 p2) acknowledge that efforts towards sustainability transformations are likely to be contested politically because "*different actors will be affected in different ways and may stand to gain or lose as a result of change.*" Government and the livestock industry wield significant political power and widely support lethal management of dingoes in the form of policies, information dissemination, capacity building and financial incentives. For example, in each Australian state there is a department, such as the NSW Local Land Services, Victorian Department of Environment Land, Water and Planning (DELWP) and Biosecurity South Australia, tasked with dingo (often referred to as wild dog) management.

Despite the barriers and lock-in traps, there is a growing number of livestock producers who have undergone transformation in the personal sphere. Their worldviews, beliefs or priorities have enabled them to transcend the barriers. Individual actors can transcend the existing 'lethal carnivore control' paradigm and cultivate a 'consciousness' that is conducive to

coexistence with local wildlife. This mentality can create profound and lasting transformational change, albeit at a local scale thus far.

In a similar way to innovative producers in the US and South Africa, their Australian counterparts critically examine the dominant assumption that killing carnivores reduces livestock predation. Some took this a step further, recognising that killing dingoes may be counterproductive to this goal, and halting landscape degradation. Indeed, killing dingoes has been shown to destabilised dingo families, killing older more experienced dingoes that have the skills to go after larger native prey such as kangaroos, leaving less experienced younger dingoes that go after easier prey such as lambs or calves (Emmott 2020). This in turn may have led innovative producers to critique their mental model and consider an alternative view. In other words, when producers acknowledge that killing dingoes can be counterproductive, that thought process can lead them to reconsider using lethal methods, and instead look for alternatives

The willingness to shift world views is a fundamental skill enabling entrenched mental models to be transcended (Ives and Fischer 2017). As Ives et al. (2020) notes, deep awareness, reflection, empathy and willingness are required to transcend existing paradigms. For example, some cattle graziers have made a personal decision to cease killing dingoes due to the belief that dingoes are essential for healthy land and productive landscapes. They have begun to share this is view with other producers (Emmott 2020; Pollock 2020; Campbell et al. 2022).

Innovative producers appear to share an expansive world view that incorporates holistic, ecological, and long-term thinking, as well as an openness to new ideas and diverse sources of knowledge about sustainable forms of agriculture. They exhibit a land stewardship ethic that aligns agroecological principles with a higher tolerance for losses to dingoes, and the goals of regenerating landscapes and encouraging species diversity. The obvious benefit is reduced persecution of dingoes, yet a stewardship ethic also benefits other species. For example, using less poison in the landscape and fewer traps has flow on benefits for improved animal welfare and landscape health (Johnson and Wallach 2016).

Perceptions of identity influence decision-making. For example, van Eeden et al. (2020) found that graziers who identify as environmentalists were less likely to engage in lethal dingo control. Similarly, Naughton-Treves et al. (2003) showed that deep-rooted social identity and occupation, such as a hunter or producer, were powerful predictors of tolerance towards wolves in the US. Acceptance or rejection of sustainable agriculture as a management philosophy is linked to a personal value system (Heitschmidt et al. 1996). In effect, innovative producers adopt a new paradigm, and this has been recognised as the most powerful tool for transformative change (Meadows 1999; O'Brien 2018).

Rockström et al. (2017 p4) articulated that a paradigm shift is needed to reposition *world agriculture from its current role as the world's single largest driver of global environmental change, to becoming a critical agent of a world transition to global sustainability within the biophysical safe operating space on Earth*. This change will require agriculture to operate under a more holistic paradigm that creates space for different ways of knowing and gentler interactions with the natural world (Gibbons 2020). However, as articulated in this paper, there are many historical and current factors that coalesce to form a lock-in to a lethal wildlife management paradigm.

Lock-in traps arise from complex social-ecological interactions, in which systems and structures, as well as the behaviour of individuals, reinforce unsustainable choices. This leads to unsustainable outcomes (i.e., loss of biodiversity and degradation of ecosystems etc.) (Boonstra and De Boer 2014; Riechers et al. 2021). Others have described lock in traps as social dilemmas where individual and group benefits are in conflict (Cumming 2018). Lock in traps can also arise from human-to-human conflicts about wildlife (Madden and McQuinn 2014) (with examples detailed in Chapter 6).

The remainder of this discussion elaborates on the four characteristics of lock in traps identified by Haider et al. (2017) (i.e., self-reinforcement, persistence, path dependencies and undesirability). I shed light on how lethal control of dingoes has become so entrenched in Australia. The shifts required to overcome this lock in are presented in the following discussion Chapter.

Self-reinforcement of a lethal paradigm

Top-down pressure is exerted through formal social norms imposed by institutions (government and the grazing industry). Formal social norms are expressed in laws, policy, preferential knowledge (research funding and available training) and financial incentives (subsidies and bounties) that are all biased towards lethal options. According to Iles (2021), once a system or regime becomes stabilised, *it tends to accrete co-evolved, enduring infrastructure, institutions, and behaviours within which actors must operate or live*. It is evident from the findings of this Chapter that factors in the political sphere, such as laws, institutional policy, incentives and information flows, are aligned with social norms that favour dingo persecution. Subsequently, institutions are resistant to change (Philip 2019). This finding is echoed by van Eeden et al. (2021) who concluded that social norms and policy conditions, such as subsidies and legislation, influence dingo management to such an extent that they focus almost entirely on encouraging, subsidising, or even mandating lethal control.

Dingoes are framed institutionally as an invasive pest due to their impact on grazing. They are referred to as 'wild dogs' by the pastoral industry and government, despite being considered a native species. The situation is further complicated because dingoes are both a declared pest (legally requiring control) and a protected native species in conservation areas (Hytten 2009; Purcell 2010). This has produced conflicting policies that both persecute and protect the species. Conflicting designations also have implications for how dingoes are perceived by the Australian public (Smith and Appleby 2018; van Eeden et al. 2020).

Obligation to control dingoes is reinforced by the National Wild Dog Action Plan, described as a 'livestock-industry driven initiative' that largely dictates the management of dingoes (Australian Wool Innovation 2020). The agriculture sector has enormous political power in Australia. For example, the Victorian Farmers' Federation describes itself as "*an active, powerful lobby group dedicated to the interests of farmers*" (https://www.vff.org.au). Their lobbying and access to government have shaped the construction of environmental and biodiversity laws such as the *Wildlife Act 1975* (the Act). Section 7A of the Act states that the Governor in Council may declare protected wildlife to be unprotected in an area of Victoria (Victorian Government 1975). The provision for 'local unprotection' was introduced in 1980, five years after the enactment of the Act (Humane Society International and Environmental Justice Australia 2020). The effect of a species being declared 'unprotected' effectively

removes any legal protections for that species under the Act. Unprotected animals such as dingoes can be shot on sight irrespective of whether they have caused damage. Consequently, landholders do not need to apply for an 'Authorisation to Control Wildlife' permit to use lethal control of dingoes in Victoria. This amendment is yet another example of how special interests have influenced legislation to their benefit. This reflects the power of the pest control narrative and the way it has shaped wildlife laws and management in Victoria. In its current form, the Act emphasises the control and exploitation of wildlife over the welfare of individual animals, and broad scale conservation of species and habitats.

Innovative producers interviewed for my Australian case study, faced intense socio-cultural pressure from neighbours and the local community to conform to social norms. Similarly, Johnson and Wallach (2016) found there was intense social and legal pressure from neighbouring farms and local governments to conform to conventional lethal practices. This pressure constitutes a barrier to adoption of predator-friendly livestock production (Johnson and Wallach 2016). Compared to economic or biological factors, social and psychological factors can have a greater influence on behaviour and the uptake of non-lethal interventions (Waudby et al. 2020). Fear of negative social repercussions and professional isolation (Smith et al. (2020), as well as the social identity around what it is to be a 'good neighbour' and farmer, also influence producers' decisions to undertake lethal control (Phillips and Gray 2007; van Eeden et al. 2020). These factors constitute socio-cultural barriers to adoption of preventive innovations.

Institutional support for local wild dog groups from the Centre for Invasive Species Solutions and Australian Wool Innovation, further amplifies local pressure to conform to lethal control. This institutional support reinforces exclusivity in social capital and ostracises innovative producers. The combination of social pressure to conform at local scale and lack of institutional support (information and incentives schemes promoting alternatives), ensures that lethal control of dingoes has become ingrained in Australian rural culture for over 200 years. Institutional structures and farming systems have solidified and persist as a lock-in trap.

Persistence of the status quo

Systems and structures in the political sphere reinforce lock in of the status quo (i.e., lethal control of dingoes). Letnic et al. (2012) highlight the role of Australian political structures in maintenance of these practices, and the exclusion of non-dominant voices. van Eeden et al. (2017) suggest the status quo has arisen through an over-representation of certain politically powerful interest groups (e.g., hunting and agriculture) in decision-making. Concentration of industry power in Australian agriculture creates a barrier to the mainstreaming of alternative ways of farming such as agroecology (Iles 2021). This concentration of power maintains a status quo that serves the interests of some species at the expense of the collective interests of all species, in this case to the detriment of wildlife, especially dingoes.

Consideration of the interests of predators is especially important in the political arena where decisions impact their welfare and survival. Santiago-Ávila et al. (2019) argue that it is necessary to consider the interest of predators in cases when human actions may harm or affect them. Conversely, the interests and lives of dingoes are seen as expendable by powerful groups. Institutions consider dingoes to be declared 'pests', and powerful interest groups (i.e.,

peak agriculture bodies and governments) fail to acknowledge the value of dingoes in the Australian landscape.

Fleming et al. (2014 p112), the "*adaptive management of wild canids inherently requires compromise and agreement between groups of stakeholders*" yet the liberal use of lethal control implies a marginalisation of stakeholders who see value in coexisting with dingoes. As a result, the voices of researchers, environmentalists, Indigenous Australians, and animal protection groups appear to be excluded from policy decisions. In summary, the concentration of the agricultural industry's political power has contributed to the resulting systems and structures (i.e., policies and laws), and further reinforced the paradigm of lethal wildlife management in Australia.

Path dependencies

Path dependencies can cause rigidities in systems and maintain a lock-in to a particular circumstance or 'solution'. For example, in Australia, wool, beef, dairy and wheat are key food export commodities (National Farmers' Federation 2017) inherited as a result of their introduction during British colonisation. European agricultural practices were transplanted to the Australian continent, despite being less suited to the conditions than Indigenous food and fibre (Iles 2021). The replication and persistence of European agriculture reflects historical path dependencies in Australian farming (Iles 2021). In the same vein, I argue that historical, institutional, and economic path dependencies continue to drive lethal control of dingoes. Governing institutions can be hampered by a lock-in to policies and actions of the past, limiting opportunities to innovate (Harries and Penning-Rowsell 2011; Davila et al. 2020; van Eeden et al. 2020). This lock-in to past decisions limits the ability of institutions to evolve with and adapt to contemporary societal values such as animal welfare and sustainability (van Eeden et al. 2017). Understanding path dependencies and how they influence perceptions and knowledge, could be a key lever for sustainability transformation (Abson et al. 2017).

Over time lethal control has become acceptable, ensuring a lower likelihood of change. The use of poisons to kill dingoes commenced in 1814 with the introduction of sheep by European settlers, and aerial baiting followed in 1947 (Fleming et al. 1998; Philip 2019). (Smith et al. 2020b) argue that the use of lethal control over an extended period has allowed it to become familiar and deeply rooted in culture.

New non-lethal approaches, on the other hand, require producers to acquire new skills, networks, and technology, or make up-front investments that might not be entirely recovered (Smith et al. 2020). These barriers can lead to preventive innovations being 'locked out', not because the innovations are not effective but rather due to practical and political factors that make it challenging for producers to adopt them, or for policymakers to seriously consider them. Even innovations that are mature (in terms of practice, knowledge, and networks) elsewhere, can founder under these circumstances (Iles 2021). This situation stands in stark contrast to farmers' relatively rapid adoption of other improved environmental practices, such as minimum tillage, when encouraged with institutional support (Thomas and Freebairn 2007; Tullberg et al. 2007).

Currently, dingo management is controversial and expensive. Economic path dependencies are created when government financial support is available for lethal control but not for preventive non-lethal innovations. Lethal methods (e.g., trapping, poison baiting, bounties) are

supported by state government agencies to varying degrees. For example, the South Australian Department of Primary Industries and Regions (PIRSA) promotes baiting, shooting and trapping as part of an integrated control program (PIRSA, 2021). This includes offering: 124,250 commercially manufactured baits to land managers free of charge; a $1.2 million trapper program (between 2018 and 2022) in conjunction with the sheep industry and landscape boards; and a $21 million drought support package that subsidises an additional full-time wild dog trapper, baiting and a $120 bounty for each dead dingo in drought affected areas (PIRSA, 2021). In Western Australia, landholders form Recognised Biosecurity Groups under the *Biosecurity and Agriculture Management Act 2007* (BAM Act). Recognised Biosecurity Groups are funded by a compulsory levy, the Declared Pest Rate, which is matched by the state government (Department of Primary Industries and Regional Development, 2021).

I found little evidence of training or financial support offered to farmers for preventive non-lethal methods (e.g., livestock guardian animals or improved animal husbandry). Smith et al. (2020) found that even where preventive innovations have been demonstrated to be effective, as is the case for livestock guardian dogs, uptake has remained relatively low. In part, low uptake of preventive innovations is due to lack of government support and incentives.

The interviews suggest that state subsidies for lethal control, particularly where obscured within other policy objectives (such as drought relief), can result in farmers' expectations of ongoing support as a 'service'. Landholders may become socially conditioned to believe that killing dingoes will automatically improve farm profitability. This creates a cycle of self-reinforcement that is difficult to break. The key consequence of lock-ins is that they create path dependencies favouring perpetuation of the existing regime (Iles 2021).

Undesirability

The confluence of social and environmental events contributes profoundly to the creation of lock-in traps (Boonstra and De Boer 2014). Social ecological systems, such as commercial livestock production systems, can become caught in both problem-causing and problem-enhancing feedback loops referred to as traps. Lock-in traps can lead to undesirable social, welfare, ecological and economic outcomes (Cumming 2018).

Carnivores are sentient and sapient beings that are self-aware and possess rich emotional and cognitive lives (Hovardas 2018; Wallach et al. 2018). In addition to direct harm, lethal programs may cause additional suffering through the experience of witnessing individual or social group members being injured and killed (Wallach et al. 2018). Dingoes have been found to respond to the death of a conspecific in the wild population in similar way to species such as primates, elephants and some cetaceans (Appleby et al. 2013).

Government sanctioned lethal methods, such as poisoning and trapping, represent an animal welfare concern because they do not cause an instantaneous death, but can injure, maim and cause prolonged suffering to both target and non-target species (Smith et al. 2020). Meat baits filled with the poison sodium fluoroacetate (1080) are widely distributed to kill canids across Australia with the aim to reduce impacts on grazing industries (Sherley 2007). The poison, 1080, is a popular control agent due to its potency, low financial cost and ease of use (particularly in pre-prepared baits) (McIlroy 1996). Baiting generally occurs twice per year in autumn to kill adult dingoes before they breed, and in spring to kill juvenile dingoes (Allen 2012). The humaneness of an animal control method relates to the overall welfare impact

that the method has on an individual animal (Sharp and Saunders 2011). For example, Sherley (2007) developed criteria to determine the humaneness of poisoned baiting that includes speed and mode of action, appearance and behaviour of affected animals, experiences of human victims, long-term effect on survivors, and welfare risk to non-target animals. Based on these criteria, Sherley (2007) concluded that 1080 should not be considered a humane poison.

The efficacy of poison baits is also in question in relation to cattle production, with cases showing baiting to be counterproductive to reducing calf loss; losses of calves were reportedly higher in baited than non-baited areas (Allen 2014; Campbell et al. 2019). Campbell et al. (2019) concluded that ground baiting, as applied, was ineffective in protecting calves. Disrupting dingo social groups through reducing a pack size or removing experienced adults that can kill larger, more difficult prey, may encourage dingoes to target livestock (Allen 2000). Furthermore, a destabilised group may increase reproductive rates and immigration, resulting in a population dominated by juveniles (Wallach et al. 2009; Wallach et al. 2010). Livestock loss is not automatically related to dingo abundance (Smith et al. 2020).

Leg-hold traps are widely used but remain controversial due to negative welfare impacts for target and non-target species. Sharp and Saunders (2011) developed an assessment of the humaneness of trapping that includes degree of physical injury, duration of restraint, method of killing, effects of exposure or dehydration, as well as propensity for anxiety, fear and stress. A key drawback of traps is they are not target-specific. A variety of native animals, such as wombats, kangaroos, wallabies, brushtail possums, birds and goannas, have been found in traps intended for canids (Fleming et al. 1998; Marks 2008). Toothed steel-jawed leg-hold traps pose a high risk of serious injuries, including compound fractures, dislocations and amputations of the trapped limb (Fleming et al. 1998). Efforts to improve the humaneness of traps led to recommendations for padded steel-jawed traps (e.g., soft catch traps). However, wallabies when caught in soft catch traps continue to suffer serious injuries, including limb dislocation. Varanids have also been known to experience dislocations and death from hyperthermia (Fleming et al. 1998). The clear benefit of preventive non-lethal innovations is a reduction in the negative welfare and conservation impacts to dingoes and other animals from poisoned baiting and trapping. These potential benefits will remain unrealised until this deadlock can be broken.

The lethal control of dingoes not only has significant welfare consequences it also undermines biodiversity conservation and contributes to a loss of ecosystem resilience (Wallach et al. 2010; Johnson and Wallach 2016; Pollock 2020). The widespread encouragement of lethal control of dingoes is a lock-in trap that results in undesirable ecological impacts such as reduced trophic regulation and meso-predator release, and potentially negative impacts on vegetation growth and structure (Letnic et al. 2009b; Wallach et al. 2010). Studies show that dingoes reduce the density or alter the behaviour of introduced meso-predators e.g., wild cats (*Felis catus*) and red foxes (*Vulpes vulpes*) via trophic regulation, thereby assisting the survival of smaller native species (Letnic et al. 2009a; Wallach et al. 2010; Letnic et al. 2012). Dingoes regulate prey species, which in turn benefits plant communities (Glen et al. 2007; Letnic et al. 2009b; Wallach et al. 2010). Further positive flow on effects may occur for Australian livestock grazing enterprises (Prowse et al. 2015).

This current lethal paradigm focuses heavily on the cost of dingoes to agriculture (Binks et al. 2015) with unequal consideration of the intrinsic value of dingoes, as well as their potential benefits (Prowse et al. 2015; Johnson and Wallach 2016). Instead of identifying and promoting ways to reduce the vulnerability of livestock to predation, such as via guarding (Van Bommel and Johnson 2012), legislation, policy, funding and research have focused on lethal dingo control (Fleming et al. 2014; Philip 2019). Socio-cultural, institutional, and economic factors, as well as personal worldviews, have caused a 'lethal lock-in' paradigm in Australia. This lock-in trap creates significant and widescale impediments to the adoption of environmental sustainability in Australian agriculture and hinders conservation of Australia's biodiversity. Furthermore, as van Eeden et al. (2021) argue the 'nil tenure' approach that advocates widescale baiting, imposes a time, financial, and environmental burden on cattle producers who are unaffected by, or may benefit from, the presence of dingoes.

Across all land tenures, including in and around national parks and reserves where dingoes are notionally protected lethal control and exclusion fencing currently receives majority funding. As Brink et al. (2019) argue there is a clear need to expand the dingo management tool kit beyond lethal control and exclusion fencing. Short-term compensation schemes may assist some farmers during the transition to non-lethal approaches, or help cover potential losses, which might otherwise be difficult for producers to accept.

Preventive non-lethal innovations constitute an important leverage point for human-carnivore and human-wildlife coexistence, yet their adoption is greatly inhibited by the lock-in of lethal control internationally and within Australia. This chapter emphasises that greater attention must be paid to the political sphere to overcome lock-in.

There are three main limitations of this research. Firstly, despite my attempt to include a range of diverse stakeholders the sample size is small (n=21). Secondly, I was unsuccessful in recruiting livestock producers and government representative from the Norther Territory to interview. This is unfortunate due to the extensive cattle operations that occurs across the state. Thirdly, I did not cover in-depth the differences between raising cattle and sheep. Across Australia, there is a difference between sheep and cattle in relation to threat posed from dingoes. It appears from my research that producers in favour of preventive innovations raise cattle not sheep, and solutions for protecting sheep are different to cattle.

7.6 Conclusions

This chapter provides an in-depth examination of the barriers to coexistence in the Australian context with the dingo. The chapter highlights that the most significant barrier to the uptake of preventive innovations in Australia exist within the political sphere. This corresponds with the findings of chapter 6. Within the political sphere, the lock-in to lethal persecution of dingoes appears to operate predominantly at two scales – informal and local (local socio-cultural norms, peer pressure etc.), and formal and wide scale (institutions, policy, capacity building and financial incentives etc). Interactions between the two scales (evident as industry lobbying, path dependency, selective knowledge transfer etc.) amplifies this cycle of conflict with dingoes in agricultural landscapes.

Using the four characterises of lock in traps, self-reinforcement, persistence, path dependencies and undesirability, my findings shed light on how the lethal control of dingoes has become ingrained in conventional livestock production. Despite the existence of lethal lock-in traps, a small number of innovative producers have transcended the barriers and adopted preventive innovations. They have transitioned away from conflict with dingoes to coexistence. These innovative producers exhibit a holistic and interconnected worldview that weighs the benefits equally beside the costs of dingoes. They prioritise long-term ecological resilience over short term economic gain and perceive themselves to be part of nature rather than having dominion over nature.

Chapter 8: Discussion of key findings

"In 2040, this business of running round in the bush, trapping dogs [dingoes] and poisoning them will cease as it's not sustainable long term. Just from an economic point of view, this is not sustainable long term because as soon as you stop, it all comes undone, so you're not making headway, all you're doing is just holding back the tide. The tide will win, eventually".

State government representative, Wild Dog Program, Victoria

8.1 Contribution of the thesis

My thesis aims to catalyse transformation towards sustainable agriculture by identifying pathways to human-carnivore coexistence. The main contributions of this thesis lie in the expansion of knowledge, the identification of innovative practices and the description of system transformation (transition pathways and a potential desirable future) to promote human-carnivore coexistence in extensive rangelands grazing systems.

Coexistence is a state where humans and carnivores share an environment without risk of exclusion to either (Chapron and López-Bao 2016). It is composed of multiple dimensions, such as temporal, spatial, social, and institutional facets. Glikman et al. (2021) and encompass how people relate to and live alongside wildlife in ways that are peaceful and mutually beneficial (Marchini et al. 2019). I investigated the concept of coexistence in relation to extensive grazing of livestock in rangeland ecosystems. Specifically, I explored various ways to keep livestock safe from predation and large carnivores safe from human persecution, especially through the adoption of preventive innovations. My thesis contributes to a body of knowledge about ways to foster tolerance with large carnivores as an important step towards achieving coexistence (Glikman et al. 2021).

In this chapter, I discuss the key findings of this study in relation to the research questions:

- *What is the rationale for building human-carnivore coexistence in rangeland ecosystems?*
- *What are the key pathways to foster human-carnivore coexistence?*
- *What are the major barriers that impede the adoption of preventive innovations and how do they operate across the focal countries?*
- *What are the leverage points to facilitate adoption of preventive innovations by the Australian grazing industry?*

The thesis draws on work by Moore et al. (2014) that identifies a three-phase framework of transformation (preparing for a transformation, navigating the transition, and institutionalising the new trajectory, which I refer to as 'stabilising the new paradigm'). Moore's three-phase framework serves two purposes in this discussion. Firstly, it enables analysis of the contribution of this thesis to the three phases of transformation towards human-carnivore coexistence (see Table 7). Secondly, the framework enables an assessment of where the focal countries of South Africa, US and Australia (presented as case studies) are situated along a transformation continuum. Thereby, using Moore's framework I clarify the actions required to complete the transformation from conflict to coexistence.

Analyses of the case studies (presented in chapters 5, 6 and 7) relied on (O'Brien 2018) reframing of Meadow's Leverage Point Framework (Meadows 1999). Meadow's framework considers processes of social transformations in relation to interacting 'spheres' of transformation: practical, political, and personal. Through this lens, I identify transition pathways in change models (presented in chapter 5) and analyse empirical data on barriers to change (chapters 6 and 7). Overall, I illustrate how carnivore management can transform from business-as-usual lethal approaches to human-carnivore coexistence.

Table 7: Thesis contribution to phases of transformation within Social-Ecological Systems

Transformation phases	Sub processes	Contribution of the thesis to phases and sub-processes
Pre-Transformation	Social-Ecological Systems crisis presents a window of opportunity	Chapter 4 (Boronyak et al. 2020) presents the evidence for the contribution of human-carnivore co-existence to biodiversity conservation. There are 4 rationales for building coexistence capacities in extensive rangeland livestock production systems: (1) livestock production is a dominant terrestrial land use; (2) large carnivores provide critical contributions to ecological functions; (3) the persecution of large carnivores has high ethical, welfare, reputational and social costs; and (4) a growing body of evidence shows that lethal control can be counterproductive to reducing predation risk.
Phase 1 Preparing for change	Sensemaking - analysis of the structures that are most problematic for the current trajectory	Chapters 5 (Boronyak et al 2021), 6 and 7 contribute to sensemaking by articulating how and why the business-as-usual system of lethal carnivore control and the barriers inherent in that system, create a lock-in to the unsustainable trajectory of wildlife loss and harm.
	Envisioning - generating new innovations and visions for the future	Chapter 5 (transformation models for South Africa and the US) and Chapter 8 (transformation model for Australia) envision desirable transformed future system of sustainable agriculture that embeds wildlife coexistence.
	Gathering momentum - self-organisation around new ideas, creation and mobilisation of networks of support,	Chapter 2 (literature review) and Chapter 4 (the rationale for coexistence), and Chapter 5 (transformation models) collectively aim to motivate action and mobilise support for human-carnivore co-existence. Chapters 5, 6 and 7 I document the existence of 'niches' of innovation and experimentation among

	and experimentation in protected 'niches'	innovative livestock producers. These niches demonstrate the emergence of self-organisation despite systemic barriers to change. The niche of preventive innovations can be supported by NGOs, industry and government to mobilise transitions.
Phase 2 Navigating the transition	Selecting innovation or change process to invest social, intellectual, and financial capital	I articulate multiple pathways for investment by system actors to create an enabling environment for coexistence. These pathways are grounded in evidence from the South Africa and US (Chapter 5), and Australia (Chapter 8) case studies.
	Learning - evaluating the results of earlier experiments and developing shared understandings or new forms of knowledge	In-depth interviews with key informants were conducted to evaluate innovative producers' experiences, reflections, lessons and barriers to adopting preventive innovations. These data were analysed to answer the research question: *What are the major barriers that impede the adoption of preventive innovations and how do they operate across the focal countries*? Data synthesis and presentation in Chapters 6 and 7 show the greatest barriers lie in the political sphere. This enabled identification of overarching leverage points to overcome these barriers (later in Chapter 8).
	Adoption - widespread uptake or replication of innovative niche	Compiling lessons from the most effective coexistence programs (Chapter 8), I create new knowledge about why and how these programs facilitated coexistence.
Phase 3 Institutionalising the new trajectory	Routinisation - managing dynamic stability to embed new trajectory and establish or strengthen new feedbacks	Not explored in this thesis.
	Strengthening cross-scale relationships - scaling up the change	In Chapters 4 and 8, I document the case of the US Department of Agriculture (USDA) Wildlife Services (WS) program which funds the implementation of non-lethal strategies across 12 states. The program aimed to reduce or prevent depredation on livestock by wildlife.
	Stabilisation of the new transformed system	Outside the scope of this thesis.

The thesis builds on previous, largely survey-based research van Eeden et al. (2020) that explored factors such as nationality and social identity to explain attitudes toward conservation actions such as lethal or non-lethal control of large carnivores. The van Eeden et al. (2020) survey compared responses between subgroups who identified as farmers, environmentalists, animal rights activists and wildlife conservation advocates. A key limitation of the van Eeden et al (2020) study was that its breadth did not allow the capture of more nuanced, context-specific attitudes toward wildlife management interventions. In contrast, this thesis employs deep qualitative engagement. Through semi-structured interviews with a range of system actors across three countries, this thesis provides rich case study narratives from a range of perspectives. Despite differences in farming systems, policy environments and socio-cultural contexts, my approach to data collection expanded on previous studies (Bogezi et al. 2019; van Eeden et al. 2019). I document underlying similarities in commercial rangelands grazing enterprises to enhance the understanding of social dimensions of transformation.

8.2 Thesis findings

The remainder of this discussion is structured around three key findings that emerged from my research.

- Firstly, a discussion on the similarities and differences in the barriers to the adoption of preventive non-lethal innovations across the three focal countries – US, South Africa and Australia – drawing on evidence presented in chapters 6 and 7.
- Secondly, a discussion about the overarching leverage points to overcome barriers in the political sphere, and how to catalyse system transformation towards human-carnivore coexistence.
- Thirdly, I identify pathways towards coexistence with dingoes developed through empirical data collected in Australia (chapter 7), and a cross-country synthesis.

8.2.1 Barriers to the adoption of preventive innovations

Three countries were selected as discrete case studies - South Africa, the US and Australia. This multi-country analysis of commercial rangeland grazing systems enabled greater insight into universal barriers to the adoption of preventive innovations. These countries were selected due to vast areas being allocated for extensive livestock grazing (Havstad et al. 2007; Seyfang and Smith 2007; Palmer and Bennett 2013), and long histories of human-carnivore conflict. Preventive innovations encompass a variety of non-lethal tools, technologies and practices that aim to proactively prevent livestock predation (Boronyak et al. 2020). These methods aim to foster tolerance, acceptance and less violent interactions. Reducing predation is an important component of building producer tolerance for large carnivores. For example, guarding livestock and carnivore deterrents lessen the need for lethal options that indiscriminately kill a variety of wildlife. Preventive innovations can improve animal welfare and conservation outcomes Schurch et al. (2021) and therefore constitute an important leverage point to achieve transformation towards human-carnivore coexistence. However, preventive innovations form only part of what is required for a transformation towards coexistence.

In catalysing transformational change towards sustainability, Abson et al. (2017) argued that attention must be paid to human actors and their social and political behaviour in addition to institutional dynamics. Actions of key agricultural actors (conventional producers, industry and government agencies) maintain the lock-in of the lethal control paradigm. Transformation of a Social-Ecological Systems toward a more sustainable trajectory is rare because the existing structures are typically mutually reinforcing and powerful actors tend to be resistant to transformation pressures and work to keep the dominant system in place (Moore et al. 2014).

Across the three focal countries to varying degrees, a confluence of socio-cultural, institutional and economic factors in the political sphere solidifies a system of lethal carnivore control. This aligns with the findings of other studies that show that the relationships between people and wildlife are greatly influenced by political and economic processes (Durant et al. 2022). Barriers in the political sphere operated in a similar way in Australia and the US to create an institutional lock in trap. The key findings presented in Chapters 6 and 7 showed that the structures and systems in the political sphere have become rigid and resistant to change. The power of industry and government and structures and systems reinforce the current 'business-as-usual' lethal paradigm. This resistance to change has been termed a lock-in trap (Boonstra and De Boer 2014). Institutional lock in traps "*emerge not by design, but evolve incrementally, often to serve narrow political and economic interests*" (Angeles et al. 2021 p2). They conserve existing systems of power and inequalities. Steneck et al. (2011) coined the term 'gilded trap' to explain a situation which occurs when greater consideration is given to economically attractive opportunities, more so than concerns about social and ecological risks or consequences. This thesis clearly demonstrates that barriers in the political sphere impede niche preventive innovations from becoming mainstream, and limit system transformation.

This thesis makes a major contribution by deepening the understanding of lock-in traps in agriculture, and their potential solutions to assist natural resource managers to work more effectively within the socio-political contexts of conservation, policy, and management (Cumming 2018). Lock-ins are characterised by self-reinforcing, inflexible, and change-resistant bureaucratic systems that overemphasise top-down control and stability (Angeles et al. 2021). This situation can lead to what Cumming (2018 p2) refers to as undesirable management syndromes in which "*sets of co-occurring actor and system behaviors, such as overharvesting or social conflict, negatively impact natural resources and/or the communities that depend on them.*" Across the focal countries to varying degrees socio-cultural, institutional and economic factors exert both top down and bottom-up pressures to continue lethal control of carnivores. A combination of historical, ideological and cultural factors has resulted in institutional 'lock-in' to policies and actions of the past that are constraining system adaptation, innovation and transformation (Harries and Penning-Rowsell 2011; Davila et al. 2020; van Eeden et al. 2020). As Treves and Karanth (2003) point out, coexistence between humans and carnivores is dependent on tolerant socio-political landscapes as well as favourable ecological conditions.

Chapter 7 details how lethal options are widely used across Australia to control the density and range of dingo populations. Use of lethal control is deeply entrenched in socio-cultural norms and institutions, which are reflected and perpetuated in the political sphere. Institutions are intentional constructions that dictate the structure of information by promoting or suppressing certain messages. In turn, this creates incentives or disincentives for

actions in a particular situation. In this way, institutions impose barriers on the range of possible behaviors and reforms (Polski and Ostrom 1999). I conclude that institutional overreliance on lethal mechanisms crowds out opportunities to adopt preventive innovations (Boronyak et al. 2020; van Eeden et al. 2020; Smith et al. 2020).

Australian government agencies enforce legislation across states in which landholders are legally obligated to control dingoes, referred to as 'wild dogs', irrespective of whether a dingo has harmed livestock or human safety. Under the *Pest Plants and Animals Act 2005,* wild dogs and dingoes are declared pest animals in the Australian Capital Territory (ACT), and landholders must take steps to control declared pests. In both Queensland (*Biosecurity Act 2014*) and New South Wales (*Biosecurity Act 2015*), dingoes and wild dogs are considered a biosecurity threat (Australian Government 2014; NSW Government 2015). The general biosecurity obligation requires a person to take all reasonable and practical measures to prevent, minimise or eliminate risk. In this case, the obligation is to minimise the risk of any negative impacts of wild dogs on their land or neighbouring lands. In NSW, under section 138 of the *Biosecurity Act 2015*, a person who contravenes a biosecurity direction is guilty of an offence (NSW Government 2015). Furthermore, government biosecurity staff have reported that they have been advised by their employer not to use 'dingo' in communications specifically because using this term in relation to lethal control may elicit a negative response from the public (unpublished data in van Eeden 2015). "*Language contributes to a cycle, either virtuous or vicious: language expresses paradigms, and reinforces them. A change of language, in turn, has potential to challenge deeply held beliefs, and potentially shift them*" (Ives et al. 2020 p 213). The reference to dingoes in industry and government policy as a 'wild dog' and 'invasive pest' acts to devalue them and legitimise the lethal paradigm.

In Australia, policy, legislation and operational decisions about the management of dingoes are shaped by narrow vested interests that wield significant power. This power dynamic was evident in response to a proposal to reintroduce dingoes into the Grampians National Park (Gariwerd) in Victoria. In the Greater Gariwerd Draft Landscape Management Plan 2021 that aimed to restore native ecological systems and culture, a proposal to reintroduce dingoes to the park was rejected due to outcry from sheep graziers (Sheep central 2021). The fifteen-year draft plan was developed in collaboration between Parks Victoria and three Traditional Owner groups: the Gunditj Mirring Traditional Owners Aboriginal Corporation, Barengi Gadjin Land Council Aboriginal Corporation and the Eastern Maar Aboriginal Corporation (Parks Victoria 2020). However, when the plan was released for community consultation in 2021, it was fiercely opposed by local landowners and graziers who held concerns that the dingoes would endanger nearby livestock (Parks Victoria 2020). Although the plan provided an opportunity to align Indigenous aspirations with long overdue reforms for dingo conservation, it was quashed. Despite growing public support for rewilding initiatives to maintain or restore dingoes in the landscape as top carnivores, narrow interests continue to overpower efforts to democratise dingo management (van Eeden et al. 2021). The combination of laws, polices and power creates institutional inertia in the political sphere that stifles progress towards the implementation of alternatives.

Similarly, in the US, industry and government institutions strongly support the lethal paradigm. The funding structure of wildlife agencies relies heavily upon the sale of licences that allow licence holders to kill wildlife through activities such as hunting, trapping and fishing (Decker et al. 2016). Dietsch et al. (2019 p 36) argues that "*wildlife management in the US, including its institutions and culture, traditionally revolves around an ideology of domination, in which policies and practices that cater to groups of people who participate in activities that result in death or harm to wildlife so long as it benefits humans in some way*". In wildlife management, the over-representation of politically powerful interest groups, such as agriculture and hunting, hinders the ability of governments and other institutions to adapt to growing societal values such as mutualism with nature (van Eeden et al. 2017). Power is concentrated in individuals and groups who support lethal control. The voices of other stakeholders who represent environmental or animal protection interests are often overpowered. This power imbalance further entrenches lethal options as the default. Innovation is key to transformation, yet the institutions charged with fostering innovation are locked into old approaches, and lethal methods of intervention (Moschitz et al. 2015).

The impact of institutions was less pronounced in South Africa as the lethal control of carnivores is not funded by government or industry. However, socio-cultural barriers are still a prominent influence in the political sphere as rural communities organise region-wide hunting of carnivores. Culture is a powerful subjective construction that influences human-environment relationships (O'Brien 2018). Across the three countries, all innovative producers interviewed had experienced socio-cultural pressure due to their alternative approaches to carnivore management. Social and cultural norms influence attitudes and behaviours toward wildlife, ranging from persecution and intolerance to tolerance and coexistence (Jordan et al. 2020). Failure to address the disparity in social norms, attitudes, and knowledge about carnivores between different human groups can undermine coexistence (Carter and Linnell 2016a).

The focal countries studied here have all had European colonial histories. Consequently, there is a dominant Western culture with predominantly Christian anthropocentric values (Schultz et al. 2000). This has fostered beliefs that humans are separate from and in opposition with nature (Suchet 2002). Across Africa, the traditionally negative European perception of the wolf was transferred to other large carnivores such as wild dogs (Zimmermann et al. 2010). In the US, the extermination of wolves began as early as 1630 where settlers in Massachusetts were offered cash payments to kill wolves and obtain hunting dogs. Towns were mandated to set baits and traps, largely to protect livestock industries (McIntyre 1995). These efforts were duplicated across the US, leading to the near extirpation of gray wolves from the 48 conterminous states by the 1930s.(McIntyre 1995; Stone et al. 2017). Recent efforts to protect or restore native predators have caused resentment among rural communities in the US (Macon 2020).

In Australia, the proliferation of a European style of agriculture over the past two centuries has degraded landscapes and imperilled Australia's unique biodiversity (Massy 2017; Pollock 2020). Harmful agricultural practices can be tracked back to the actions of white settlers who were incentivised by "*government policies that encouraged (and even forced) farmers to clear natural vegetation from their properties under terms of conditional purchase*" (Cocklin and Dibden 2009 p4). European colonisation also contributed to the negative image that has been

constructed around the dingo (Parker 2007). Consequently, 'dingo control' has been undertaken ever since dingoes first came into conflict with early European settlers (Parker 2007). This created a legacy that devalued native Australian species and embedded widespread lethal wildlife control in legislation and policy.

Colonial histories across the three countries have shaped socio-cultural norms that legitimise and encourage lethal carnivore control. There are pervasive colonial beliefs that lethal control is necessary to mitigate the risk that carnivores pose to human life, livelihoods, and livestock. Colonialism has also created socio-cultural stigma to the adoption of preventive innovations that offer alternatives to mitigate predation risk. Efforts to bring about transformations towards sustainability are likely to be deeply political and contested, especially where they diverge from current socio-cultural and institutional norms and traditions (Patterson et al. 2017).

This next section discusses the leverage points needed to break the most significant barriers to change. I discuss institutional, socio-cultural, and economic barriers, which all lie in the political sphere. Systems and structures form 'the political sphere' because they are created, codified and managed through political processes (O'Brien 2018). The political sphere is where cooperation, collaboration and compromise can lead to the formation of new alliances and social innovations (Meadows 1999; Meadows 2009).

8.2.2   Overarching leverage points to create transformation in extensive grazing

Considering the literature, and empirical data from the three case studies, I have identified three global leverage points to facilitate human-carnivore coexistence. These leverage points aim to address institutional, economic, and socio-cultural barriers to change. Leverage points include agitation by NGOs to mobilise support for transformation, policy reform, good governance and creation of a culture of coexistence.

The role of NGOs to mobilise support for transformation

Partnerships between environmental and animal protection NGOs are essential for transformative change. I argue that NGOs play a critical role in facilitating 'deliberate transformations' and breaking the institutional lock-in (government and agri-industry) that pervades the political sphere. NGO actors aim to intentionally disrupt the political sphere that has become rigid and locks in Social-Ecological Systems across three countries in an unsustainable trajectory. Conservation NGOs attempt to steer transformation towards biodiversity conservation. In doing so, these organisations influence the trajectory of the transformation process (Moore et al. 2014).

Transformation of Social-Ecological Systems requires disruption at multiple scales. Everard et al. (2016) demonstrated how key individuals or small-scale initiatives can 'scale-up' to precipitate broader social and institutional shifts in values, norms and practices. In some cases, the first step toward institutional change has been in the form of a 'pilot project' to test the effectiveness of alternative approaches. A successful example of transformation towards human-carnivore co-existence is the Wood River Wolf Project from Idaho, US. The Wood River Wolf Project demonstrated how a range of non-lethal tools and practices can be used to mitigate predation losses. The Project used preventive innovations including herding sheep into night corrals surrounded by turbo fladry (portable electrified fencing with flags to deter

wolves), herders and livestock guardian dogs, and light and sound deterrents(Stone et al. 2017). The Project effectively maintained low rates of livestock predation and carnivore killing. On average, only five sheep per year (.0025%) of 20,000 sheep in the region are lost to wolves annually and only two wolves have been killed in the project area since efforts began in 2007 (Stone pers. comm). The proven efficacy of non-lethal methods catalysed an institutional shift within Wildlife Services in Montana. A coalition of environmental organisations financially supported the hiring of Wildlife Services staff dedicated to implementing non-lethal tools and approaches (Young et al. 2019; Boronyak et al. 2020).

The success of the Montana Partnership (Chapter 4) led to a breakthrough for preventive innovations in the US. In 2020, the US Department of Agriculture (USDA) Wildlife Services (WS) allocated $1.38 million to implement and evaluate non-lethal predation management tools across 12 US states (APHIS 2020). The program operates on a cost-sharing and cooperative funding model. Across states including Arizona, California, Colorado, Idaho, Michigan, Minnesota, Montana, New Mexico, Oregon, Washington, Wisconsin and Wyoming, state WS directors collaborate with state and local agencies, non-government organisations and academia (APHIS 2020). Efforts were directed into three key areas:

- Human resources - Hiring of full-time or seasonal employees to implement non-lethal methods (range riding, installation and maintenance of fencing and fladry);

- Capacity building - Presenting workshops, educational sessions, and outreach activities that promote the best techniques for use of non-lethal methods; and

- Equipment - Purchasing non-lethal tools and scare devices for immediate use or to establish loan programs for producers.

The Wood River Wolf Project, Montana Partnership, and USDA WS program, show that the US has progressed into phase three of the transformation that I refer to as stabilising the new paradigm. This is because strong cross-scale relationships are stabilising the new trajectory and the new paradigm of human-carnivore co-existence (Moore et al. 2014). Integrating staff with expertise in non-lethal tools and practices into a government department has the potential to break the institutional lock-in to the lethal paradigm. These examples show how NGOs can use external mechanisms referred to as 'societal levers' to progressively integrate emergent societal values into institutions that are typically imbued with substantial inertia ((Everard et al. 2016). We see the status quo challenged in the political sphere, leading to the formation of new social movements to address structural injustices (O'Brien 2018). However, as Moore et al. (2014) also point out, active resistance from powerful actors at different scales is likely in the stabilisation phase. Such resistance has been observed in Idaho and Montana where the hunting of wolves has been liberalised to such an extent that prominent ecologists have raised concerns about the future viability of wolf populations in the Rocky Mountains (IWCN 2022).

Policy reform for coexistence

Policy reform is required to de-legitimise lethal control, increase public participation in wildlife decision making, and introduce new governance structures that balance human and wildlife needs (Carter and Linnell 2016a). Policy reform can combat the normalisation of lethal carnivore control across the three countries.

Effective and equitable governance are essential to achieving sustainable sharing of agricultural landscapes with wildlife (Redpath et al. 2013). Good governance embodies representation, participation, deliberation, accountability, empowerment and justice (Lebel et al. 2006). Governance creates the structures and processes for ordered rule and collective action (Folke et al. 2005; Lebel et al. 2006). Institutions that achieve representation of and participation by diverse stakeholders, form an important part of adaptive governance systems (Daily et al. 2009). The development of good governance requires an understanding of the complex and interdependent linkages between social and ecological variables (Partelow 2018). Effective environmental governance requires "*negotiation, monitoring, collaborative learning and connectivity across organisations and institutions at various scales for maintaining the desired state of the social- ecological system*" (Stern, 2018 p 174).

Fostering coexistence requires mechanisms for addressing conflicting priorities (Carter and Linnell 2016b). Central to policy reform are government policies and programs that encourage and enable coexistence and non-lethal solutions to human-wildlife conflicts. Such reform would require the provision of technical assistance, education and support for landowners to use suitable preventive innovations. Reform also requires proof that non-lethal methods have been exhausted before lethal control can be authorised, as is the case with the Oregon Wolf Plan (Oregon Department of Fish and Wildlife 2014). Landholders, requesting a damage mitigation application must provide evidence of the losses caused by wildlife and proof that the loss was caused by the target species. Effective governance is also necessary to address the overrepresentation of narrow interests that perpetuate the lethal lock-in.

A good case study of effective governance is the Blackfoot Challenge in western Montana. The Blackfoot Challenge oversees the management of a 1.5-million-acre watershed. Formed in 1993, it took a collaborative approach to conservation in the watershed. As per collective action theory, actors self-organised and cooperatively formed an institution to improve natural resource governance (Partelow 2018). Initially, the organisation focused on weeds, river management and fencing. This approach built trust between diverse groups of ranchers, landowners, local business owners, government agencies and conservation experts, before tackling carnivore management. By widening the scope from carnivores to other issues of importance to landholders, trust can be built, and openness to perspectives of people that would be considered external to landholders' reference group can be established (Stern 2018). In 2002, grizzly bear conflict escalated so a Landowner Advisory Group was formed to listen to the concerns of diverse local groups and advise the Challenge on conflict reduction strategies. This paved the way for implementation of preventive non-lethal tools and practices in 2003, such as removal of grizzly bear attractants including carcasses and boneyards from ranches. The Challenge organised carcass pick-ups and a composting program (Wilson pers. comm). Promoting tolerance of large carnivores requires management frameworks that incorporate a range of values that are mutually beneficial for humans and carnivores (Smith et al. 2020). The

formation of the Blackfoot Challenge facilitated the mobilisation and coordination of resources, as well as participatory decision making (Burnett 2013, Wilson et al. 2014, Wilson 2016). Community-based approaches such as this demonstrate how it is possible to balance the needs of carnivores, rangeland livestock operations and rural communities (Macon 2020). These approaches create a favourable institutional and cultural environment that supports – rather than stifles – coexistence.

Fostering transformation towards coexistence is an integral part of sustainable agriculture and involves "*the intentional breaking down of specific resilience of the old system (including value path dependencies) and building resilience in the new system*" (Rigolot 2018 p1). Therefore, it is important to understand the old paradigm. In particular, it is essential to characterise the power dynamics and politics that enable and undermine shifts towards sustainable agriculture. It is crucial to identify barriers that impede improvements in livelihoods, society, and protection of biodiversity and the wider environment (Rockström et al. 2017).

To date, according to Moore et al. (2014), there has been limited insight into the role of power in transformation processes. There has been a tendency to downplay the political nature of constructing alternative human–environment relationships. To deal with the challenge of transforming old paradigms, there are increasing calls for wildlife management to be more inclusive and democratic (Fox and Bekoff 2011; van Eeden et al. 2017). To foster coexistence, (Carter and Linnell 2016a) suggest the adoption of novel decision-making structures that can ensure participation and legitimacy. These novel structures would involve diverse stakeholders external to the grazing industry, and government agencies, such as First Nations peoples, and conservation and animal protection NGO representatives. The inclusion of diverse knowledge systems and experiences in decision making is an important part of adaptive governance of Social-Ecological Systems (Folke et al. 2005).

The Convention on Biological Diversity 2020 'Global Diversity Outlook 5' report called for transformational changes to address biodiversity decline. Recommended changes included strengthening environmental laws and policies and their implementation (Secretariat of the Convention on Biological Diversity 2020). Incorporating the public trust/interest principle could provide a mechanism for improved governance, transparency and accountability in the regulatory framework that governs wildlife management. Public Trust Doctrine (PTD) is a model to ensure that diverse knowledge systems and experiences are included in decision making. PTD is a legal concept that originated in Roman law and later developed in English common law. Its premise is that certain natural resources cannot be effectively or fairly managed by private owners (Sagarin and Turnipseed 2012). Enacting a public interest principle would ensure that the diversity of interests held by the community are properly represented as part of good governance. Incorporating PTD in policy reflects the growing interest in the ecological and aesthetic value of nature (Sagarin and Turnipseed 2012). PTD also provides accountability mechanisms, ensuring that regulation of wildlife serves the diversity of public interests not just powerful lobby groups. PTD could be a powerful tool for advancing ecological interests in law and policy.

Several countries including South Africa, US, Ecuador and India have used 'PTD-type' language in their biodiversity laws or constitutions to incorporate the basic principles it embodies (Sagarin and Turnipseed 2012). In the US, PTD establishes a trustee relationship of government management of the consumptive use and protection of natural resources such as wildlife, fish, and waterways in the interest of the public (Batcheller et al. 2010). Bruskotter et al. (2011) notes that the doctrine establishes a legal obligation for US state governments to conserve species on behalf of all citizens, present and future. Natural resources are deemed universally important in the lives of people (Batcheller et al. 2010). For example, the state-trustee may not privilege private interests over the general public. The trustee must refrain from taking actions that impair species such as the removal of a large numbers of carnivores through liberalised hunting (Bruskotter et al. 2011). If the government fails to meet this obligation, citizens can seek legal redress in the courts (Sagarin and Turnipseed 2012). Reforms such as this provide an important counterbalance to the disproportionate power of special interest groups in wildlife management.

Creating a culture of coexistence

The 'pest control' narrative driven by agri-industy remains a powerful cultural force especially in Australia. This narrative drives the wide scale killing of wildlife to improve agricultural productivity. In my research, this worldview and was evident in the narratives of conventional livestock producers.

Cultural change is an evolutionary process that helps human societies adapt (Beddoe et al. 2009). Faced with the rapid loss of biodiversity, cultures will need to adapt to assure our survival and that of species whose fates are interwoven with our own. Cultural practices, such as agriculture, fundamentally impact upon nature (Hytten 2009). Changes in human culture, values and social order, although difficult, are necessary to address species extinction (Ives and Fischer 2017). There are increasing calls within the field of conservation science to consider culture and values in addressing ecological challenges (Manfredo et al. 2017; Ives and Fischer 2017). Social values, culture and world views can change, often within a few decades, yet momentum for change needs a strong social movement that can mobilise public opinion, exert political pressure, and create cultural resonance (Elzen et al. 2011; Everard et al. 2016).

The Lion Guardians conservation program in Kenya is a prime example of where aspects of culture were successfully used to reduce negative interactions between pastoral communities and carnivores. Retaliatory killing of African lions (*Panthera leo*) by Maasai pastoralists caused a decline in the lion population, threatening local extinction (Hazzah et al. 2013). Lion Guardians used an integrated approach to reduce the underlying causes of predation, which included the use of preventive innovations, participation, and science to improve local tolerance of large carnivores. Community cultural value systems were incorporated into the program (Hazzah et al. 2014). Prior to the program, lions living in pastoralist areas were poisoned or speared in retaliation for livestock predation, and to reinforce the role of warriors (ilmurran) in Maasai society. Ilmurran are responsible for protecting the community and livestock (Hazzah et al. 2009). The program employed respected ilmurran as Lion Guardians and leveraged their traditional leadership roles to prevent lion persecution. If the guardians learn of a planned lion hunt, they used social pressure to discourage their peers by arguing that hunting is illegal, negatively impacts tourism, and can be detrimental to compensation

payments. They explained how the guardians' livelihoods depend on lion presence (Hazzah et al. 2014). In Maasai culture, causing problems for another, particularly a well-respected community member, is frowned upon. The employment created through the program is also an important benefit from lion conservation that positively influenced Maasai attitudes toward lions and reduced propensity to kill lions (Hazzah et al. 2013).

The Lion Guardians program had a range of benefits. The Guardians recovered 11,240 lost livestock worth over $1,000,000, found 18 lost child herders, and tracked lions to warn herders to take action in high-risk situations (Hazzah et al. 2014). The cultural norms among Masai shifted to such an extent that lion killing almost ceased entirely in each area where the program was implemented (a 99 per cent decline). This shift has been sustained over the long term (Hazzah et al. 2014). People who were once lion killers transformed their identity to become lion guardians, thus demonstrating that change in culture and values can improve community wellbeing and foster coexistence with large carnivores. The program also provided a sense of community ownership of lions by monitoring lions on community land through traditional methods and radio tracking (Hazzah et al. 2013). This shift in culture in relation to large carnivores, such as lions, may be described as a growing culture of 'consciousness for coexistence'. Approaches such as this, that build on existing deep cultural relationships with large carnivores, are fundamental to valuing carnivores as a social as well as a natural resource (Durant et al. 2022). Understanding worldviews, values and beliefs is necessary to cultivate a coexistence consciousness and facilitate deep transformation.

Individuals may not be aware of the impact that culture and society have on them, and how they, in turn, impact their environment (Schlitz et al. 2010). Many conservation scientists have highlighted the need for a better understanding of the factors that influence stakeholders' attitudes towards carnivores. Cultural and social factors influence decisions relating to how we interact with carnivores, the design and targeting of conflict mitigation activities, and tolerance towards carnivores (Naughton-Treves et al. 2003). Gordon (2018) argues that the extent to which livestock management actions impact on carnivores depends largely on the beliefs, values, perceptions, attitudes and distribution of livestock farmers. Tolerance of carnivores plays a critical role in their conservation (Zimmermann et al. 2010). A greater understanding of the capacity to tolerate wildlife assists in facilitating coexistence between humans and wildlife with minimal repercussions to each other (Bhatia et al. 2020).

8.2.3   Pathways towards coexistence with dingoes in Australia

This section of the discussion focuses on the final research question- *What are the leverage points to facilitate adoption of Predator Smart Farming by the Australian grazing industry*? I articulate six pathways that have the potential to leverage transformation in Australian grazing systems to create a new movement towards Predator Smart Farming with coexistence with dingoes as a core component (Figure 9). The concept of pathways is used to communicate plausible stories about large-scale transformations (O'Brien 2018).

The six pathways and future vision have been synthesised from key informant interviews in Australia, key policy documents that informed the findings of Chapter 7, and deep reflection on the findings of Chapters 4, 5 and 6. The pathways aim to find ways to balance multiple stakeholder interests and overcome the lethal lock-in. I argue that Australia has progressed only as far as phase one - preparing for a transformation - as efforts to date have been

directed to the sensemaking, envisioning and momentum building processes. Since Australia lags behind South Africa and the US in terms of progress towards a transformation, international examples of interventions are used to illustrate the types of successful actions associated with each pathway that could inform action in Australia.
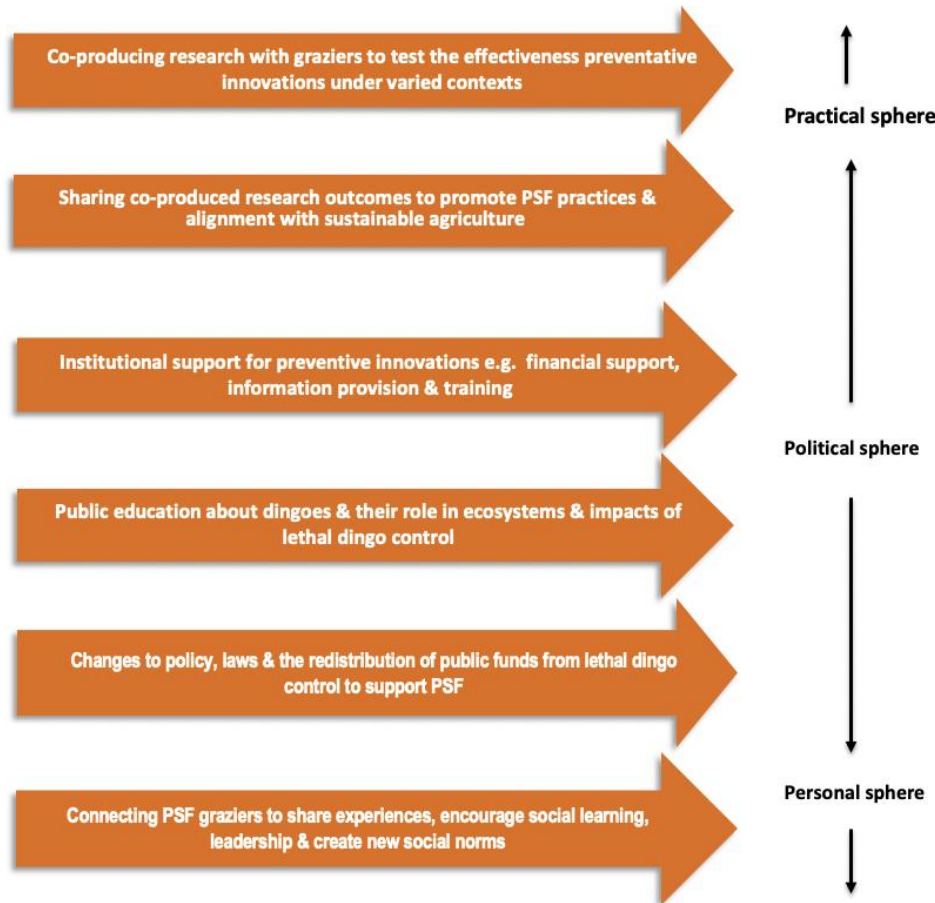
Figure 9: Pathways from conflict to coexistence with dingoes

Pathway 1 – Collaboration and co-production in research

The first pathway 1 (P1) falls primarily within the practical sphere but has overlaps with the political sphere. P1 focuses on collaborations to co-produce research that investigates the efficacy of preventive innovations in a range of contexts such as cattle or sheep grazing and rangeland ecosystems. P1 shifts the focus from managing dingo numbers via lethal control towards managing the negative impacts of dingoes for graziers. P1 retains and enables the positive effects that dingoes have on ecosystems (Brink et al. 2019). The efficacy of a variety of preventive innovations would be tested to understand the conditions under which they are most effective, and to build capacity to implement the most suitable approaches for a specific context. This iterative process of focused, independent, experimental research would create a sound evidence base for a range of preventive innovations (Brink et al. 2019). P1 uses collaboration to understand and prevent factors that may underlie human-carnivore conflict (Zimmermann et al. 2010), and then proactively prevent livestock predation. This pathway is important to build tolerance and acceptance of wildlife and foster coexistence (Frank et al. 2016).

Local knowledge is key to identifying practical solutions. A collaborative approach draws upon local knowledge to achieve this. Livestock producers are a key stakeholder group in research and decisions regarding non-lethal methods. Adoption of non-lethal methods would likely be facilitated via greater collaboration and mutual understanding with producers. The risks that dingoes pose to extensive livestock grazing means that graziers must be engaged as part of an integrated and collaborative approach. There is growing literature on the potential to combine local knowledge systems (such as First Nations people or local communities) with scientific knowledge for improved ecosystem management (Gadgil et al. 2009).

The adoption of preventive innovations often requires new skills, competencies, networks and technologies (Smith et al. 2020). According to Marchand and (Lauwers 2010), farmers can acquire new knowledge, skills and attitudes through individual experimentation and learning (e.g., trial and error) or via networks that advocate social learning. Social learning involves deliberative interactions amongst multiple stakeholders. Participants learn from each other, work together, and build relationships that facilitate collective action and trust (Cundill and Rodela 2012). Social learning can be beneficial in conflict situations because it requires people to learn how to work together. A combination of the contextual, constructive, and reflective aspects of social learning aids the acquisition of new knowledge and can catalyse changes in the personal sphere (norms, perceptions, attitudes and behaviours) (Marchand and Lauwers 2010; Moschitz et al. 2015). During social learning interactions, participants may "*co-create new meanings, develop their practices and rebuild their identities*" (Moschitz et al. 2015 p 3). Co-learning is important to refine protocols around each preventive innovation and inform the selection process (Moore et al. 2014).

Community engagement and social learning proved successful in the Blackfoot Challenge in Montana. The Challenge has taken a collaborative approach to conservation and fostered human-carnivore coexistence by engaging residents in meetings, workshops, field tours, and research. This action has built effective partnerships and working relationships (Wilson pers comm). For example, permission was sought from dozens of ranchers to conduct an annual winter wolf survey across their land. Local volunteers were recruited to conduct the survey (Wilson et al. 2017). This co-generation of research data led to a more collective understanding of wolf numbers, distribution, and activity, and built trust, ownership and credibility of information about wolves among stakeholders (Wilson et al. 2017). Collaboration, cooperation and social learning are fundamental to successful management of Social-Ecological Systems (Rodela 2011).

Pathway 2 – Knowledge sharing networks

Pathway two (P2) has overlapping actions in both the practical and political spheres. This pathway builds on P1 through dissemination of the co-produced research outcomes to promote adoption of Predator Smart Farming practices. Predator Smart Farming takes a Social-Ecological Systems perspective to recognise the importance of carnivores to healthy ecosystems. It integrates ecologically sensitive and sustainable practices from agroecology and regenerative grazing to increase the resilience of livelihoods, landscapes and livestock. This form of farming emphasises the use of non-lethal tools and practices that deter or mitigate conflict and increase livestock resilience. These tools are not only effective (Stone et al. 2017; van Eeden et al. 2018a) but are more acceptable to the public (Slagle et al. 2017), and

preferable from an ethical and conservation standpoint. P2 aligns Predator Smart Farming with similar movements that advocate sustainable agriculture. This pathway fosters coexistence through practical solutions, outreach, credible ecological information, and the social psychology of the people affected (Zimmermann et al. 2010).

An example of P2 is evident in the Shepherding Back Biodiversity Project run by the Landmark Foundation in South Africa. The Landmark Foundation works with livestock producers to assist a transition to predator smart practices. The Foundation conducts economic and ecological monitoring (https://www.landmarkfoundation.org.za/fair-game/) and provides professional consultancy in non-lethal methods such as guardian dogs. Producers achieve a price premium through 'Fair Game' branding. In addition, participating producers receive compensation when domestic animals are killed by carnivores. The program has been successful for both carnivores and producers. The average cost of predation declined by 70 per cent regardless of the non-lethal method adopted (McManus et al. 2015). The Foundation purchased a farm in the Karoo region of South Africa to demonstrate a range of predator smart practices. Holistic resource management was adopted as a grazing practice. This involved a time-controlled, rotational grazing system with high-density, short duration grazing in paddocks, followed by long 'rest' periods without livestock to allow vegetation to recover (Savory and Butterfield 1999). On the Foundation's Karoo farm, Schurch et al. (2021) identified that strategic shepherding of livestock under a holistic resource management regime aided ecosystem restoration and virtually eliminated predation. Livestock were guarded, kraaled at night and densely herded together. There was only a single loss to predators in 3 years (Boronyak et al. 2021; Schurch et al. 2021). Here, holistic management combined with wildlife friendly farming and the cessation of lethal control was not only profitable but over 3 years resulted in a 24 per cent increase in species richness and 73 per cent increase in the relative abundance of herbivores (McManus et al. 2018). Night kraaling of livestock increased trampling and concentration of manure. Over time, this resulted in nutrient-rich, heterogeneous patches and increased vegetation cover (McManus et al. 2018). The improved vegetation productivity on this farm compared to neighboring properties that used conventional set stocking and lethal carnivore control, indicates that Predator Smart Farming can improve rangeland productivity and resilience (Hasselerharm et al. 2021). While holistic resource management is not specifically advocated for Australian rangelands, the Landmark Foundation's Karoo farm demonstrates the potential of altered management regimes to reduce predation.

As a single-issue, Predator Smart Farming will face limited traction with livestock graziers in Australia due to the barriers detailed in Chapter seven. A way to mobilise support for Predator Smart Farming is to align it to knowledge sharing networks associated with larger ecological movements such as regenerative grazing, some of which have gained a foothold in agriculture. This accords with conclusions of Brink et al. (2019 p373) who suggest that the socio-ecological benefits of dingoes may be *best conserved through a holistic approach to management, including increased investment in innovative combinations of non-lethal conflict-management tools and strategies*. The regenerative grazing movement in Australia has focused on ecosystem regeneration and carbon sequestration. So far, regenerative grazing has overlooked the contribution of dingoes to ecosystem health underpinning rangeland agricultural productivity. However, alignment with regenerative grazing could be an important way to progress human-dingo coexistence. It could raise awareness, and mobilise support and

resources for retaining dingoes across rangelands as summed up by this quote from a non-government organisation representative:

> "*If dingo friendly or predator friendly farming was one tool in the toolkit of being about regenerative agriculture, then maybe they* [graziers] *would think more positively about it in that way.*"

<div align="right">Australian conservation representative 1</div>

The following three pathways fall within the political sphere and focus on the role of institutions in public education, policies and funding to foster human-dingo coexistence.

Pathway 3 – Building institutional support and capacity for Predator Smart Farming

P3 advocates for greater institutional support for preventive innovations. Institutions in this context refer to governments, the meat and livestock industry, and NGOs involved in conservation or animal protection. In P3, these institutions would offer financial support and capacity building (information and training on non-lethal alternatives) to assist producers cover the upfront costs of trialling and adopting preventive innovations. Furthermore, the risks of adoption could be reduced by a transparent compensation scheme for proven livestock losses to dingoes. Transcending lethal practice lock-in requires not only innovative thinking but also NGO, consumer, and public pressure to push for institutional change.

A leading example of institutional support for preventive innovations is the Montana Partnership. Formed in 2017, between environmental NGOs and the US Wildlife Services in Montana, this partnership was pivotal to building institutional capacity for Predator Smart Farming. The Partnership investigated the use of a non-lethal tool, turbo fladry, to reduce human-carnivore conflict. Turbo fladry consists of strands of flags (50 by 10 cm) sewn onto electrified poly-wire at 45cm intervals. Turbo fladry causes a shock when an animal touches it (Young et al. 2019). No livestock predations occurred across the 28 turbo fladry projects despite the presence of a range of carnivores including wolves, grizzly bears, black bears, coyotes and foxes (Young et al. 2019; Boronyak et al. 2020). The Montana Partnership was effective because Wildlife Services was allowed to access farms, and NGO Natural Resources Defense Council staff had practical knowledge of the use of turbo fladry (Young et al. 2019). This partnership created institutional support for preventive innovations, built new social norms to redress socio-cultural pressures, and provided financial support for preventive innovations to be mainstreamed.

In Australia, a few conservation NGOs advocate for dingo conservation such as the Humane Society and Australian Dingo Foundation. However, the institutional and financial influence of governments and the grazing industry in support of lethal practices outweighs the resources of these NGOs. Recently, Brink et al. (2019) proposed a novel way to collect funds for dingo-conservation that could be channeled towards research of non-lethal tools and strategies. This proposal capitalises on Australians' love for domestic dogs with either a levy on domestic dog food (0.6%) or a one-off animal-sales levy (1.2% of the cost of domestic dogs) to raise AU$30 million or more annually, thereby matching the estimated AU$27 million that is currently spent on dingo management by state agencies (Brink et al. 2019). One could argue that companion animal owners should not be the ones paying (in effect) to subsidise activities in livestock industries. Other potential funding streams (e.g., funds from compulsory levies, peak

industry bodies, regional grants, certification schemes, philanthropy) and the redistribution of funds for lethal control (see Pathway 5) may also be viable alternatives.

Pathway 4 – Public education and public pressure to modernise wildlife management

P4 advocates a public awareness campaign about dingoes. The campaign aims to raise awareness of the impact of current management practices, and the ecological importance of dingoes. P4 also calls for public pressure on government to modernise Australia's approach to dingo management. This pathway capitalises on the growing body of animal welfare and conservation research relating to the important role of dingoes in the health and function of ecosystems (Letnic et al. 2012; Letnic et al. 2013). For example, it draws on research findings that link the loss of dingoes to the irruption of foxes, and widespread losses of small and medium-sized native mammals (Letnic et al. 2013). P4 incorporates the creation of space to discuss dingo management, non-lethal solutions, and improved conservation, animal welfare and public safety.

Currently, across Australia, there is low awareness among the general public of dingo management (van Eeden et al. 2019). A recent survey of 811 Australians revealed that only 19% were aware that wild dog management included dingoes (van Eeden et al. 2021). This confusion in the minds of the general public is likely to have arisen from dingoes being labelled as wild dogs in policy and legislation (Brink et al. 2019; van Eeden et al. 2021). The majority of respondents (85%) considered dingoes to be native to Australia and supported the use of non-lethal methods (e.g., livestock guardian animals and fencing) as alternatives to lethal methods (i.e., shooting, trapping, aerial baiting and ground baiting) (van Eeden et al. 2021). Respondents showed slightly more support for killing wild dogs than dingoes (van Eeden et al. 2021).

The 2005 ban on hunting foxes with hounds in the United Kingdom is an international example of P4 (Anderson 2006). This form of hunting had been practised for 300 years. However, there was mounting public and political pressure to stop the hunts. Political pressure came from Labour Members of Parliament supported by anti-hunting pressure groups, such as the League Against Cruel Sports, the Royal Society for the Prevention of Cruelty to Animals and the International Fund for Animal Welfare. Ultimately, this pressure brought about a ban due to animal welfare concerns (Anderson 2006).

In relation to dingoes, an awareness raising campaign is clearly needed to reduce public confusion and fill information gaps. Most importantly, a campaign is needed to galvanise NGO and public pressure towards state and federal environment ministers to restrict lethal control. Poisoned baiting should be restricted on public lands such as national parks, and funding should be re-allocated towards research and adoption of preventive innovations (van Eeden et al. 2021). Overcoming information gaps would involve targeted dissemination of research by scientists and NGOs, as well as the sharing of experiences and knowledge of innovative graziers and First Nations Peoples. Information would be disseminated to government representatives, the meat and livestock industry, conventional producers, and the general public. There is a real role here for conservation and animal welfare NGOs as change makers. These actors not only raise awareness of the animal welfare, ecological, economic, and social consequences of lethal control options, but also push for policy change, as seen in the US. As an Australian conservation representative said:

"I think the public awareness and valuing of dingoes, is a major leverage point. There is contention around dingoes, and wild dogs, and their definitions, which means that people aren't as clued on to what's happening, as they might otherwise be."

Australian conservation representative 1

Pathway 5 – Institutional change

P5 focuses on creating institutional change in terms of policy, legislation, and redistributing public funds from lethal control of dingoes to Predator Smart Farming. However, this requires fundamental re-calibration of the policy foundations such as:

- Emphasising the conservation and protection (at an ecosystem level) of the diversity of wildlife over the lethal control and exploitation of wildlife
- Introducing a public trust or interest principle that creates obligations on the state and its agencies to manage wildlife for the benefit of all Australians including future generations
- Establishing a new and independent regulator to effectively govern, implement and enforce stronger regulations and policies which support responsible wildlife management, and build social tolerance and coexistence with wildlife
- Legislation that supports and prioritises non-lethal management as a first response
- Funding to establish a multi-disciplinary advisory committee to investigate and develop a range of strategies, policy responses and programs to incentivise preventive innovations, and foster sustainable coexistence, and ensure a conservation approach to wildlife management
- Bringing dingoes into the broader conversation about biodiversity conservation
- Engagement with politicians as agents of change

Chapter 7 showed how agri-industry, in collaboration with government, dictates the policy agenda. These powerful actors provide asymmetrical information about dingoes, and influence which initiatives and research are funded. Certain types of information are disseminated or withheld depending on whether they support or destabilise dominant power structures (Abson et al. 2017). Information about predation risk, disseminated from government and industry to producers, is inherently biased towards lethal control. This is important because institutions facilitate the production, inclusion and dissemination of knowledge within a decision-making process. (Beddoe et al. 2009) identified that institutions, technologies and world views, are mutually interdependent and mutually reinforcing. Industry capture of the policy process by these groups has undermined the broader public interest in wildlife management.

In addition to legislative and policy reform, a central component of P5 is the re-allocation of a portion of dingo-management budgets towards adoption of preventive innovations, and a compensation scheme. Currently, dingo-management budgets are allocated almost entirely to lethal control and/or exclusion through the installation of large landscape scale fencing (Brink et al. 2019). The provision of bounty payments for lethal control would need to be withdrawn, along with subsidies and funding for baiting. Financial incentives for lethal control (e.g., bounties for dingo scalps) cement the non-selective lethal treatment of dingoes that can destabilise dingo families (Zimmermann et al. 2010). Baiting efforts are jointly funded through public and industry support, yet the lack of target specificity can worsen livestock predation especially for the cattle industry (Zimmermann et al. 2010; Allen et al. 2015; Campbell et al.

2019). Studies from Queensland and South Australia reported that calf losses to dingoes were higher in poison baited than non-baited areas. As the scale and timing of foetal or calf loss was not correlated with dingo activity and that ground baiting, as applied, was ineffective in protecting calves (Campbell et al. 2019).

Alternative incentive schemes are needed to facilitate the adoption of non-lethal methods. Incentive-based strategies such as the payments for the presence of wildlife aim to improve attitudes and behaviour toward large carnivores by distributing the benefits of carnivore presence more equitably (Hazzah et al. 2014). A policy transition towards Predator Smart Farming would seek to balance agri-industry and conservation interests, reduce the need for controversial and expensive management decisions and create a culture that is accepting of coexistence with dingoes and other native wildlife.

Pathway 6 – Social capital development

The final pathway, P6, falls within the personal sphere and overlaps with the political sphere. P6 addresses barriers identified in the political sphere (e.g., socio-cultural, institutional, economic), and aims to alter their influence on the personal sphere (e.g., worldviews, beliefs, priorities and identities) (Hedlund-de Witt 2012). This pathway focuses on connecting innovative graziers to share experiences, encourage social learning and foster peer-support. P6 harnesses leadership to shape new social norms and identities and build a sense of reciprocity and trust. Forming these connections is integral to the development of social capital (networks, support and knowledge sharing) (Putnam 2001). A supportive network would help graziers to withstand the intense socio-cultural, institutional and economic pressures to conform to the use of lethal options.

Decisions to adopt preventive innovations are influenced by what is considered socially and culturally acceptable by members of the potential adopters' social or reference group (Stratford and Davidson 2002b; Amel et al. 2017; Stern 2018). Support from likeminded communities is vital to facilitate coexistence. Chapter seven described the intense difficulties individuals encounter when they act alone to adopt alternative approaches without support, in the face of adversarial pressure from their peers and wider industry.   argued for a greater acknowledgment of "*the strong influence of groups (e.g., cultural affiliation, formal organisations, social classifications, norms) on how people think and behave*" in relation to wildlife management. As environmental practices are often new subcultures, a supporting environment of family, neighbours, and peers shapes the acceptability of this new farming subculture and associated norms (Stratford and Davidson 2002). Overcoming socio-cultural barriers requires the development of an alternative culture, changes to worldviews, and institutional adaptations.

The ability of graziers to transcend the existing lethal control paradigm and cultivate a 'consciousness' that is conducive to coexistence with local wildlife has the potential create profound and lasting transformational change. A consciousness for coexistence discourages the intentional killing of wildlife, thereby improving welfare and conservation outcomes. In this way, P6 facilitates a shift away from an unsustainable regime reliant on lethal control to a more sustainable social, ecological and economic system (Beddoe et al. 2009).

A transformed future system for Australian grazing

As with the change models presented in Chapter 5, it is anticipated that progress along these pathways would lead to a future transformed system in Australia with attributes consistent with transformed systems in the US and South Africa. Sustainable farming systems would be embedded into agriculture to enhance biodiversity, landscape resilience, food security, and provide satisfying livelihoods for farmers. The mainstream adoption of Predator Smart Farming would become an integral part of sustainable agriculture. The transformed system would see the restoration of the role of dingoes as apex predators, and the re-establishment of diverse species and healthy functioning ecosystems. Scientific and evidence-based approaches would play a greater role in policy than politics. Dingo ecology and behavior would inform management decisions. In addition, sufficient public and private investment would be allocated to research, education, and outreach. This reallocation of funding would create an enabling environment for the adoption of preventive innovations as part of Predator Smart Farming. Farm gate prices would reflect the value of animal welfare and internalise the costs of agricultural production.

8.3 Limitation of the thesis

This thesis has seven main limitations. Firstly, the thesis is focussed on commercial livestock grazing in the context of industrialised agricultural systems, therefore the results may not be transferable to subsistence livestock farming. Subsistence farming occupies large areas of rangelands in countries other than the three examined here. Some of the non-lethal tools and practices may be relevant or already used to mitigate predation in subsistence systems.

Secondly, as human-carnivore conflict is a global phenomenon case studies can be yielded from any countries. Resource and time constraints led to the pragmatic decision to concentrate on international case studies in the US and South Africa where I had existing contacts that could assist in arranging interviews with key stakeholders.

Thirdly, there was a high proportion of participants who practiced non-lethal approaches. Arguably higher than the actual population of producers. This was deliberate as I sought to understand what preventive innovations they had tried and adopted, their experiences with preventive innovations, the barriers they faced with the innovations themselves as well as socially and economically etc.

Fourthly, I did not distinguish between raising sheep and cattle. For example, in Australia, cattle graziers may be less inclined than sheep graziers to use lethal control as dingoes pose less of a threat to healthy adult cattle. However, calves are vulnerable to predation (Allen and Sparkes 2001; Letnic et al. 2012). From the interviews, there was a strong preference among sheep graziers for lethal control of dingoes, and the sheep industry makes considerable investment into these options, likely 'crowding out' research and investment in non-lethal options.

Fifthly, the thesis did not detail the economics of increased labour for herding, the installation of preventive innovations, or the learning curve associated with implementing preventive innovations. Some of the non-lethal practices identified here, may call for increased labour inputs. The long-term adjustment that substitutes capital for labour (e.g. Swinnen et al. (2005),

existing labour shortages and relatively high labour costs World Bank (2021) exacerbated under COVID-19, may pose significant economic constraints. Many of the graziers I interviewed said they operate under marginal profitability, so the costs of hiring of additional labour would affect adoption of some practices under Australian conditions. These barriers to adoption warrant further investigation.

Sixthly, and related to the last point, this thesis did not explore the potential for new emergent technology (automation, robotics, drones, artificial intelligence, remote sensing etc) to labour input. New technology is likely to have a significant impact on landscape and livestock management in the future.

Lastly, due to COVID restrictions I was unable to travel to visit Australian farms to interview producers face-to-face. Almost all the interviews with Australian producers were conducted via phone or zoom. Therefore, I was unable to undertake field observations that would have improved my contextual knowledge of Australian farming systems.

Despite these limitations my thesis contributes to the development of a broader awareness of the drivers of human-carnivore conflict, uncovers the deep leverage points required to intervene to address this critical conservation challenge and seeks to promote progress along pathways toward human-carnivore coexistence in Social-Ecological Systems (Dickman 2010; Boronyak et al. 2021).

8.4 Future directions

My research has uncovered pathways required to transform from human-carnivore conflict to coexistence. Across the three countries significant effort is required to implement the various pathways to achieve Social-Ecological system transformation. The possible future directions are summarised into three key areas:

1) Stakeholder mobilisation: to raise awareness of the current management of carnivores and the implications (ecologically, socially and economically) of widescale lethal control. This would involve a review of the lethal control of carnivores to understand the magnitude of this paradigm – numbers killed, costs of lethal control etc. This could be used by NGOs to lobby governments to reform policy, legislation and economic change to support coexistence.

2) Capacity building for human-wildlife coexistence: NGOs such as the International Wildlife Coexistence Network have been established to provide expert interdisciplinary assistance, training, collaboration, and shared research to enable communities around the globe to coexist with wildlife. See wildlifecoexistence.org

3) Capacity building to adopt Predator Smart Farming: in the form of a guide that provides a practical guidance for landholders who want to coexist with local carnivorous wildlife. This guide could provide information about tools and practices that can simultaneously protect livestock and carnivores, detailed case studies of producers' experiences with implementation of Predator Smart Farming, including benefits, limitations and key lessons learned. This information aims to increase skills, knowledge, and confidence to adopt tools and practices that form part of a wider movement towards sustainable and high welfare animal agriculture. Following on from this would be training or field days to show how various preventive innovations work,

how they work based on knowledge of carnivore behaviour and ecology and tips to enable successful implementation.

The last chapter of this thesis provides succinct answers to the overarching and sub research questions.

Chapter 9: Conclusions

Agriculture is vitally important to human society and is a global driver of environmental change (Foley et al. 2005; Rockström et al. 2017). Reconciling food demands with the need for a range of ecosystem services is one of the greatest challenges of the twenty-first century (Dudley and Alexander 2017). My thesis focussed on how coexistence between humans and carnivores in rangelands used for extensive livestock grazing could be catalysed. I conclude that coexistence can be an action, a worldview, or a destination – that orients us towards living alongside local wildlife in ways that are respectful, mutualistic and peaceful.

Based on my research findings, I make five principal conclusions:

1. Need: There is an urgent need to improve human-carnivore coexistence in commercial grazing enterprises. This is because human-carnivore conflict in agricultural landscapes is driving a global decline in large carnivores, with associated secondary extinctions; violence and cruelty towards wildlife; and human to human conflicts (Woodroffe et al. 2005; Zimmermann et al. 2010; Madden and McQuinn 2014; Ripple et al. 2014a).

2. Pathways: Transformation towards human-carnivore coexistence in rangelands is achievable via pathways that reduce predation risk and increase benefits of large carnivores. These pathways include research, capacity building, and outreach for preventive innovations; partnerships for Predator Smart Farming; institutional reform; compensation and marketing programs.

3. Methods: The adoption of preventive innovations forms an important pathway to coexistence. However, adoption of non-lethal tools and practices is impeded by socio-cultural, institutional and economic factors in the political sphere.

4. Approach: Predator Smart Farming is a new and holistic farming movement that aims to balance grazing and conservation values to increase the resilience of landscapes, animals (domesticated and wild) and rural livelihoods. This form of farming, or local variations of it, is both feasible and beneficial for people, animals, and agricultural enterprises. I present strategic leverage points to facilitate adoption of Predator Smart Farming in Australian grazing enterprises.

5. Leverage points: I identify strategic leverage points to catalyse transformation towards human-carnivore coexistence such as the role of environmental and animal protection NGOs in pushing for a coexistence paradigm, policy reform and cultivating a consciousness for coexistence.

My thesis sought to answer an overarching question: *How can human-carnivore coexistence be established in extensive rangelands ecosystems?*

The short answer is 'yes', as evidenced by the 31 innovative livestock producers that I interviewed who are running profitable grazing enterprises and coexisting with large carnivores across three countries. These producers were able to transcend socio-cultural, institutional, economic and practical barriers to successfully adopt preventive innovations to safeguard livestock and local wildlife. Throughout this thesis I have included other global examples of where coexistence is working such as the Montana partnership, the Blackfoot Challenge, the Wood River Wolf project, the Landmark Foundation- Fair Game label and Lion Guardians.

In addressing this overarching question, my thesis makes four important contributions. Firstly, presenting key rationales for why we need to build human capacity for coexistence. Secondly, the identification of various transition pathways towards coexistence across three countries – US, South Africa and Australia. Thirdly, an in-depth investigation of barriers faced by livestock producers in adopting preventive innovations that impede transformations for coexistence. Fourthly, discussion of the essential overarching leverage points to support the transformation towards human-carnivore coexistence across three countries.

Using established research methods from the social sciences (primarily semi-structured interviews, field observations supported with analysis of key documents) my thesis investigated coexistence with carnivores in rangelands from multiple perspectives (livestock producers, environmental advocates, policy makers and agri-industry). It creates new knowledge of the steps required to stimulate and support transformation towards human-carnivore coexistence. I used systems thinking to facilitate a deep exploration of the factors that enable or constrain transformation by uncovering the dynamic interrelationships of different social and ecological elements in commercial rangelands grazing across three countries (US, South Africa and Australia). This approach facilitated greater understanding of the drivers of human-carnivore conflict and identification of the deep leverage points required to create transformation towards human-carnivore coexistence in landscapes managed for agricultural production (Dickman 2010; Boronyak et al. 2021).

9.1 Rationales for human-carnivore coexistence

Chapter 4 articulated the reasons why we need to transform from conflict to coexistence with large carnivores in extensive livestock grazing systems. Livestock grazing is a dominant terrestrial land use that occupies an estimated 37% of the world's ice-free land, carried out predominately in rangelands (Ferrier et al. 2019). While rangeland ecosystems are globally important for livestock production, they also support diverse wildlife assemblages and are crucial for biodiversity conservation (Hasselerharm et al. 2021). Yet native rangelands and biodiversity are increasingly under pressure while the global meat demand is projected to rise by 57% by 2050 (Hawkins 2017; Mottet et al. 2017). This places additional pressures on ecosystems and likely lead to greater conversion of wilderness areas for extensive grazing. Without intervention this will exacerbate human-carnivore conflict, resulting in the further loss of biodiversity and ecosystem services.

The loss of large carnivores has been identified as major driver of biodiversity loss and is "*humankind's most pervasive influence on the natural world*" (Letnic et al. 2013 p 102). Reducing carnivore persecution combined with restoring and maintaining the populations of large carnivores is critical to sustain biodiversity and maintain functional, resilient ecosystems that underpins agricultural productivity (Estes et al. 2011; White 2012; Letnic et al. 2013; Thorn et al. 2015; Johnson and Wallach 2016a; Schurch et al. 2021). I agree with the conclusions of Brink et al. 2019 p371 "*if we are to avoid the extirpation of large carnivores, effective means for coexistence on land shared with livestock must, therefore, be found*."

The persecution of large carnivores has high ethical, welfare, reputational and social costs. Failure to improve the environmental, welfare and social impacts of livestock production will increasingly affect livestock industries' social license to operate now and into the future (Williams and Martin 2011). Government-run wildlife management programs that carry out lethal control or provide permits for individual landholders to kill wildlife have political costs in terms of backlash from citizens as well as environmental and animal protection groups (Treves and Karanth 2003; Letnic et al. 2009b; Ripple et al. 2014). This creates conflicts between people that value and wish to protect carnivores and people that bear the cost of living alongside carnivores in terms of safety, livelihoods or interests. As shown in chapters 6 and 7 conflicts over wildlife creates division among communities, regions and nations that undermines social cohesion and can result in violent outcomes.

This thesis contributes to the growing body of evidence that lethal control can be counterproductive to reducing predation risk. Carnivores are persecuted under the belief this will reduce predation and increase agricultural productivity. However, the assumption of a direct relationship between predator numbers and impact is not always valid (Allen 2000). Lethal control provides no guarantee of reduced livestock losses and due to ecosystem feedback loops that can exacerbate livestock predation (Berger 2006; Treves 2007; McManus et al. 2015; Treves et al. 2016; Stone et al. 2017; Nattrass et al. 2020). Lethal control is also costly to individual producers in terms of time spent setting up and checking traps, distributing poisoned baits, and hunting carnivores. Evidence presented in Chapters 5 and 6 led me to conclude that coexistence tools and practices provide a viable alternative to lethal control that causes direct and indirect harm to wildlife from being poisoned to being restrained in a trap or wounded from a gunshot. Lethal control is, in of itself a trap creates a lock-in to the path towards extinction. It is imperative to find pathways to coexist with large carnivores in human dominated landscapes.

9.2 Pathways towards human-carnivore coexistence

Through in-depth engagement with key stakeholders (producers, conservationists, and government representatives) I identify important pathways to enable transition from routine lethal management of carnivores towards mutually-beneficial coexistence (chapters 5 and 8). The pathways represent transitions that culminate in longer-term transformative change. The pathways operate across a variety of scales from the local-regional level to the global level and provide a bridge between the current 'conflict paradigm' in which large carnivores are heavily persecuted towards a vision of a 'coexistence paradigm' in the year 2040. The pathways define broad actions that incorporate multiple values in grazing systems including changes to livestock management practices, marketing initiatives and a range of other initiatives including capacity building; research and outreach; economic and policy incentives; strengthened environmental laws and enforcement; as well as governance structures that balance human and carnivore needs.

The pathways identified in this thesis are mutually reinforcing to create long lasting change. Ensuring that the transformation is durable requires altering the dominant power structures and embedding the newly reconfigured social-ecological elements and feedbacks within governing institutions (Moore et al. 2014). Cumulatively, the pathways create an enabling social environment that supports preventive tools and practices to move from 'niche' to

'mainstream'. Implementation of these multiple pathways would likely lead to transformational change in the management of grazed rangeland ecosystems that ensures thriving agricultural communities, secure livelihoods, reduced violence toward wildlife, and landscapes that are productive and support species conservation and coexistence. However, change is impeded by various actors and barriers that solidify structures and systems that keep the current paradigm of conflict in place.

9.3 Barriers to the adoption of preventive innovations

My thesis aimed to fill a knowledge gap on the factors that constrain adoption of preventive innovations in extensive livestock grazing systems. Chapter 6 identifies the barriers in South Africa and US and chapter 7 details the barriers in Australia. In each I identified broad overlapping themes and also issues that were regionally distinct. I classified the barriers across three spheres- practical, political and personal to enable clear identification of the barriers, how they operate and the precise scale to apply interventions. Despite environmental and animal protection groups advocating for the adoption of preventive innovations to reduce livestock predation, and the benefits of adoption, my research suggests that there has been limited uptake among grazing communities. I conclude that barriers actively disincentivise coexistence efforts and keep the Social-Ecological Systems locked-in to the conflict paradigm.

Producers generally encountered barriers across all three spheres. Barriers in the political sphere comprising socio-cultural, institutional, and economic factors reinforce lethal approaches among most producers regardless of the efficacy or economy of alternatives. Coexistence between humans and carnivores is not just dependent on favourable ecological conditions but also on tolerant socio-political landscapes (Treves and Karanth 2003). The barriers to change, identified in chapters 6 and 7, require transformation across all spheres of influence (practical, personal and political) to create more sustainable and regenerative farming systems that accommodate a diverse array of species (Rockström et al. 2017). My contribution to understanding the barriers helps conservation and animal protection NGOs, researchers and practitioners inform approaches that facilitate wide scale adoption and 'un-locking' of benefits for landholders, wildlife, livestock, and the environment.

9.4 Predator Smart Farming

Over the past four years I have had the privilege of visiting farms and talking to producers about the costs and benefits of living alongside large carnivores. I also spoke at length with key stakeholders about niches of innovations that I have referred to as preventive non-lethal innovations, which have emerged from within farming communities and from conservation and animal protection researchers and practitioners. These innovations contribute towards broader goals of sustainable agriculture, meaningful livelihoods, and human-carnivore coexistence, which together make up aspects of Predator Smart Farming.

Throughout my research I gained a deeper appreciation for how language has the power to unite or alienate. The terms used when talking with producers are important. During interviews with producers in South Africa and in the US, I noted a negative reaction to the term 'predator friendly' which is the term preferred by coexistence advocates and consumers. Even innovative producers who refrained from killing large carnivores opposed being called predator friendly producers. The term predator smart emerged from my empirical research as

a more palatable term (for producers) to encapsulate coexistence with wildlife as a fundamental part of sustainable agriculture to safeguard land, livelihoods and livestock. There is a need for individual, collective, and institutional action to foster both incremental and large-scale change, towards ecologically sustainable agriculture (Amel et al. 2017). However, achieving the necessary change requires transformations in human-carnivore interactions and within human society across the practical and political spheres to balance the needs of humans and wildlife.

I articulated six pathways that have the potential to leverage transformation in Australian grazing systems to create a new movement towards Predator Smart Farming that allows for both the preservation of dingoes and protection of livestock:

1. Collaborations to co-produce research that investigates the efficacy of preventive innovations in a range of contexts such as cattle or sheep grazing and different ecosystems.
2. Dissemination of the co-produced research outcomes to promote wide scale adoption of Predator Smart Farming practices in grazing communities.
3. Greater institutional support (governments, the meat and livestock industry, and NGOs) for development of preventive innovations and adoption of Predator Smart Farming in commercial rangelands grazing enterprises.
4. A public awareness campaign about dingoes to raise awareness of the social, spiritual and ecological importance of dingoes and the negative impacts of lethal control to pressure state governments and mobilise the movement to modernise and democratise approaches to dingo management.
5. Institutional change to address political barriers such as legislation, and policies that advocate for coexistence coupled with the redistribution of public funds from lethal control of dingoes to Predator Smart Farming.
6. Development of social capital to influence aspects of the personal sphere (e.g., worldviews, beliefs, priorities and identities) by connecting innovative graziers to share experiences, encourage social learning and foster peer-support.

I conclude that progress along these pathways would lead to a transformed system in which the mainstream adoption of Predator Smart Farming would become an integral part of sustainable agriculture. In Australia, Predator Smart Farming could facilitate transformation toward human-dingo coexistence. Sustainable farming systems would be embedded into agriculture to enhance biodiversity, landscape resilience, food security, and provide satisfying livelihoods for farmers. Coexistence would restore the role of dingoes as apex predators, to regulate introduced species and contribute to healthy rangeland ecosystems using scientific and evidence-based approaches to inform management decisions. To mainstream Predator Smart Farming there is a need for public and private investment and partnerships to create an enabling environment for the adoption of preventive innovations as part of Predator Smart Farming.

9.5 Leverage points for coexistence

Identifying the most strategic leverage points for transformation toward coexistence from empirical evidence is an important contribution of this research. Leverage points that alter social or ecological feedbacks aim to establish and strengthen the transformation towards human-carnivore coexistence. Leverage points must be appropriate at the local landscape scale and contribute towards global efforts to conserve large carnivores. Three overarching leverage points were identified.

Firstly, environmental and animal protection NGOs play an important role in steering transformational change for biodiversity conservation and improved animal welfare. These actors catalyse deliberate transformations, mobilise support and resources that are needed to break the institutional lock-in (government and agri-industry) that pervades the political sphere. Through their actions NGO actors aim to intentionally disrupt the political sphere that has become rigid and locks in Social-Ecological Systems across three countries in an unsustainable trajectory.

Secondly, NGO actors can also agitate for policy reform that is required to overcome barriers in the political sphere. This involves reform to de-legitimise lethal control, increase public participation in wildlife decision making, and introduce new governance structures that foster coexistence to balance human and wildlife needs across the three countries (Carter and Linnell 2016a).

Thirdly, coexistence requires a shift away from a culture that normalises and enables lethal wildlife management, to one that values the life of - and actively finds ways to - live alongside diverse species. To transform to a new paradigm of coexistence we need to go beyond the adoption of preventive innovations. Fundamental change is required in personal worldviews, values, and interests, as well as transformation across social norms, culture, and institutions and the way we conduct agriculture (Ives et al. 2020). Understanding worldviews, values and beliefs is necessary to cultivate a coexistence consciousness and facilitate deep transformation. Given the social, scientific, and technological tools available, supported by advances in consciousness research and its applications, collectively we have a unique opportunity to manifest a new coexistence paradigm for our planet and humanity.

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Appendix 1: Interview guide

Interview questions for livestock producers

Part 1: About your farming enterprise

- Can you please provide a description and overview of your property (the size, type of terrain, number of staff).
- Can you describe the neighbouring properties and/or landscapes (e.g. national park, grazing land etc.)?
- What is the history of the property (i.e., for how has it been used in the past, how long has it been grazed for)?
- US only- Do you graze on a farm or public allotment
- US only- For how long have you grazed on a farm or public allotment?
- What livestock do you graze? What are the breeds?
- Do local predators influence your choice of breeds e.g choosing for herding or more aggression, why?
- Do you have a general philosophy around livestock production?
- What season do you lamb/calve?

Part 2: Interactions with local wildlife

- What wildlife inhabits or moves through the land you graze on?
- What are the interactions that occur on your land between yourself/workers, livestock and wildlife?
- What is your attitude toward local carnivores?
- What is your yearly livestock losses (e.g. how many, what are the causes of loss?)
- What is your yearly livestock losses to carnivores, how is that trending in relation to past years?
- What actions do you take to mitigate livestock losses to carnivores?
(If actions are non- predominantly lethal go to part 3, if actions are predominantly lethal go to part 4).

Part 3: Non-lethal ways to mitigate livestock losses to predators

- What actions or strategies are you taking to manage depredation on the farm?
- How efficient/effective are each of these strategies and why?
- How much $m is spent annually on risk mitigation?
- For how long have you been using non-lethal tools and practices?
- When are your livestock most vulnerable to depredation? Do you use extra strategies during this time?
- Do you have a threshold of acceptability for predation e.g 10% losses annually.
- What were the specific reasons that you decided to use non-lethal tools and practices?
- Before using use non-lethal tools and practices what actions were you taking to reduce livestock losses from predators on your land?

- Can you estimate the value or numbers of losses before using non-lethal tools and practices?
- What have been some of the benefits of using non-lethal tools and practices
  - What changes have you noticed in terms of livestock?
  - What have been some of the changes have you noticed in terms of local wildlife?
- What are the disadvantages of non-lethal tools and practices?
- What are the economic and time costs associated with implementing non-lethal tools and practices?
- Have losses been reduced since you implemented non-lethal tools and practices and why?
- Tell me about the barriers you faced in adopting non-lethal tools and practices
- Are there any benefits to having predators on or around your farm?
- Would you expect a higher return for farming in a more predator friendly way. If so how much?
- What are your trusted sources of information? E.g neighbours, other ranchers etc.
- Do you believe that using non-lethal can support producer livelihoods and conserve wildlife in production landscapes? Why/why not
- Are your neighbours using non-lethal, if not have you discussed this issue with your neighbours, friends etc?
- Do you feel pressure socially to use lethal control?

Part 4: Lethal ways to mitigate livestock losses to predators

- What actions or strategies are you taking to manage depredation on the farm?
- How much $m is spent on overall depredation mitigation?
- How much is spent on lethal control (e.g bullets, hiring people to shoot etc).
- Is lethal control undertaken by staff or outsourced to government or hunters?
- How effective are these strategies to reduce livestock depredation?
- Have you heard of non-lethal tools and practices? Y/N
- What if any practices do you do that can be considered non-lethal to predators to mitigate loss? What was the outcome/s?
- How efficient/effective are each non-lethal deterrents?
- What barriers did you experience in trying non-lethal deterrents.
- What might encourage them to try a non-lethal practice?
- Do you have any neighbours or people in your social network that use non-lethal approaches to managing predators? yes what have they told you about their experiences with these practices.

<div align="center">Interview questions for government representatives</div>

Part 1: Overview of human-carnivore conflict

- What species of carnivores are implicated in the conflict with livestock industries?
- Who are the key stakeholders/actions involved in the conflict?
    - What are the broad roles and responsibilities of these key stakeholders?
- How does your department count populations of large carnivores or assess impacts on livestock industries?

Part 2: Approaches to manage conflict or promote coexistence

- What are the various ways that human -carnivore conflicts are currently being managed by your department?
- What tools or practices are advocated by your department and why?
- What research is drawn upon to support this position?
- What are your reflections on the effectiveness lethal tools and practices?
- What are your reflections on the effectiveness non-lethal lethal tools and practices?
- Where does your organisation access information about non-lethal tools and practices? How did you acquire this information?
- What are the benefits of carnivores existing in production landscapes?
    - Prompts capture economic, cultural, ecological benefits.
- What is the role of the government in bringing about change on this issue?
    - What are the barriers for implementing this change?
- How do state government policies influence the human-carnivore conflict in the region?
- What are the leverage points for change on the human-carnivore conflict?
- What are the barriers to the adoption of non-lethal tools and practices in Agricultural landscapes?
  What is the government dept doing to overcome these barriers (solutions)?
- How can these solutions be implemented and who is responsible for this?
- What is your vision for the future on this issue out to 2040?
- Can you identify other government representative to discuss this issue with to understand the various policy perspectives?

Part 1: Overview of human-carnivore conflict

- What species of carnivores are implicated in the conflict with livestock industries and why?
- Who are the key stakeholders involved in the conflict?
- How do state government laws and polies influence human-carnivore conflict?
- How is the conflict currently being managed (i.e., lethal and non-lethal tools and practices)
  - Describe all lethal practices commonly used and their impact/s (conservation, welfare and behaviour) on large carnivores?
  - How effective are lethal practices to reduce human-carnivore conflicts?
  - Describe all non-lethal practices used and their impact/s (conservation, welfare and behaviour) on large carnivores?
  - How effective are non-lethal tools and practices to reduce human-carnivore conflicts?
- Which combinations of non-lethal tools and practices are most effective and why?
- What are the benefits of carnivores existing in production landscapes?

Part 2: Capacity building for preventive innovations

- What are the barriers that producers face when adopting non-lethal tools and practices in Agricultural landscapes?
- How does your organisation assist in overcoming these barriers?
- Where does your organisation access information about non-lethal tools and practices? How did you acquire this information? How is it shared with producers?
- What are the leverage points for change on the human-carnivore conflict?
  - What is the role of the NGOs in facilitating coexistence?
  - Who are the key stakeholders/other organizations that you collaborate with on the human-carnivore conflict in the region?
  - How does your NGO lobby government for change?
  - What do you see as the major pathways to move from conflict to coexistence?
- How can we move from preventive innovations being a niche to mainstream practice?
- It is the year 2040 what is your vision for the future on this issue?
- Can you identify other NGO representatives to discuss this issue with to understand the various policy perspective?