

Livestock Predation and its Management in South Africa: A Scientific Assessment

Editors

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Livestock Predation and its Management in South Africa: a Scientific Assessment

Edited by Graham I H Kerley, Sharon L Wilson and Dave Balfour

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Foreword

AGRICULTURE and biodiversity are both key elements of the South African economy. The management and use of livestock in support of society has been a feature of the peoples of southern Africa for over two millennia. The production of meat, fibre, skins and other animal products such as milk, on a sustainable and adequate scale are important factors contributing to the economy and food security of the country. A role of the Department of Agriculture, Fisheries and Forestry is to provide an enabling regulatory environment for the production of goods and services by the livestock industry. Equally important is the role of the Department of Environmental Affairs to provide a regulatory environment for the management of the natural environment in a manner that enables growth and development today without limiting the options of future generations.

The ecosystem goods and services that are provided by the natural environment, along with all the other benefits that humans receive from the biodiversity of our country, play an important role in supporting the lives and economies of every South African. Predators and predation are an important element of the natural landscape and functional ecosystems.

The conundrum for society is how to promote both these societal benefits when they appear locked in an unavoidable conflict between each other, livestock production vs natural predator populations in the landscape. The conflict has persisted for thousands of years with no solution; at first glance it seems like a zero sum game. The challenge is for legislators to understand and to formulate policy which is attentive to the needs and benefits of both biodiversity and livestock producers which at the same time seeks to minimize the net overall losses to society.

In this historic first (nationally and globally) Scientific Assessment covering the topic of predation on livestock in South Africa, both government departments are being afforded a single document containing detailed and current insight and knowledge on this complex situation as a basis for contemplating policy development. This assessment contributes seamlessly to the government's strengthening resolve to develop evidence-based policy and to recognise that in many complex situations, such as where there is predation on livestock, there is no silver bullet solution. Rather a process of adaptive management is required.

The partnership of government, industry, stakeholders and leading researchers that emerged to resource and formulate this Scientific Assessment provides evidence of the broad and strong commitment to address the conflicts around livestock predation management.

We are confident that this Scientific Assessment will set the stage for improved policy formulation and management of livestock predation in South Africa, thereby reducing conflict around this issue and contributing to sustaining both agricultural production and biodiversity. We thank all the role players who have made this possible.

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Assessment Governance

In order to promote the good governance of this assessment, a Process Custodian Group (PCG) was established to serve as an independent oversight body. The core function of the PCG was to ensure that an equitable, rigorous and transparent process was followed. The role of the PCG was not to determine or critique the content of the assessment. The PCG met at key junctures to review the process that had been followed and to ensure that it was fundamentally fair. The PCG consisted of six individuals, drawn from government, NGOs, industry and the research community and was chaired by an independent Chairperson. Members of the PCG were:

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Preface

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FORMAL scientific assessments are increasingly used by society to develop approaches and seek solutions to complex problems. Predation on livestock represents such a problem, in that it includes a range of social, economic, legal, ethical and management challenges to a broad range of role players (including *inter alia* livestock farmers, policy makers, conservationists) and plays out in poorly-understood natural ecosystems. The scientific assessment of livestock predation and its management in South Africa (PredSA) presented here is therefore an attempt to provide role players with a critically assessed compilation of the state of agreed-upon information in the various disciplines (from ethics to ecology) relevant to livestock predation in South Africa.

This initiative is supported by the key role players (affected government departments and livestock industry) and undertaken by a body of recognised experts in the various disciplines. Importantly, in this process, emerging best practice in undertaking scientific assessments has been followed, including careful governance of the process by an independent group, and measures taken to promote the saliency, legitimacy and credibility of the assessment (see Chapter 1 for more details). In general, assessments are based on currently known (published) information.

An unusual and ground-breaking step undertaken here has been the attempt to address information shortcomings that were identified early in the process, specifically the recognition that there is a paucity of published information on the issues around livestock predation in communal farming areas in South Africa. Accordingly, an independent research group was commissioned to undertake a survey of this issue, and these findings incorporated into the assessment.

This assessment represents a synthesis of the current state of understanding around the challenges in managing livestock predation in South Africa. Given the global nature of this problem, the assessment also draws on international experiences and lessons. The time-frame of the material included ranges from prehistoric to publications still in press at the time of this assessment itself going to press. The latter highlights a key aspect relevant to scientific assessments, this being that scientific knowledge is growing rapidly and society is constantly changing. As a consequence our understanding of, and hence approaches to, issues such as the management of livestock predation need to be changing as well. While this Scientific Assessment on livestock predation and its management in South Africa represents a global first in terms of the novel approach of commissioning of the acquisition of material to fill identified gaps in information, and is also the first assessment globally to address this topic at a national scale, it is also clear that this is not the end of the assessment process for this topic. Scientific assessments are ongoing undertakings, being revised and updated at appropriate intervals as information and the understanding of the focal topic develop. Thus, while it is intended that the information compiled here should be of immediate and relevant value to policy-makers, managers and scientists, it is also clear that the next step in the process is the assimilation of lessons learnt and emerging science to contribute to assisting South African society in dealing with the challenges around the predation of livestock.

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Graham Kerley, Sharon Wilson and Dave Balfour

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SUMMARY FOR POLICYMAKERS

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CONTEXT

This summary provides a narrative overview on Livestock Predation and its Management in South Africa, highlighting policy relevant aspects in a non-technical fashion. The assessment was undertaken by a team of experts, led by the authors of this summary, and provides extensive details, and a knowledge base of the diverse fields relevant to livestock predation in South Africa, and should be consulted for such details (and the identified gaps in our knowledge).

LIVESTOCK PREDATION AS THE SUBJECT OF A SCIENTIFIC ASSESSMENT

THE arrival of domestic animals over two millennia ago heralded the emergence of livestock predation as a source of human-wildlife conflict in South Africa, and this conflict has yet to be resolved. This is despite the virtual elimination of the largest predators (lion, leopard, spotted hyaena, African wild dog and cheetah) from much of the country, and numerous management and policy attempts to eliminate or reduce livestock predation. The persistence of this conflict reflects its complexity, with many species of predators (although currently jackal and caracal are the most prominent) playing a role in a broad variety of ecological, socio-economic and socio-political settings. Actions to address this conflict, particularly lethal control of predators, commonly elicits strong emotions in various sectors of society. Such complex issues (sometimes called “wicked problems”) may be usefully addressed by a formal Scientific Assessment, a process whereby a group of experts are mandated by key role players (in this case,

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both government and industry) to provide a policy-relevant synthesis of what is known (and not known) about an issue. Importantly, in the assessment process, a multiplicity of views and values are incorporated in order to ensure that the outcome resonates within society. The assessment of livestock predation in South Africa

summarised here represents a global first in terms of bringing the authority of a scientific assessment to bear on this source of human wildlife conflict. A key feature of this summary is that it aims to inform policy makers but avoids being policy prescriptive.

Defining livestock

The term 'livestock' generally refers to animals that are managed for human food or fibre production or that serve as draught animals. Although typically applied to conventional agricultural settings and domesticated animals (e.g. cattle, sheep, pigs, horses), the term can be extended to cover a diversity of taxa such as fenced wildlife, fish, managed game birds such as pheasants, or even silk moths. The objectives of their management can extend to providing sport or to satisfy cultural practices.

For the purposes of this assessment, livestock have been broadly defined as comprising domesticated animals and wildlife (the former excluding poultry, and the latter including ostrich *Struthio camelus*) managed for commercial purposes or human benefit in free ranging (or semi-free ranging) circumstances that render them vulnerable to predation.

Focusing the assessment findings on policy

In considering the issue of livestock predation it is necessary to bear in mind that predation is a natural process. It is not only important as a driving factor in the evolution of the landscapes within which we live, and the biota that inhabit them, but is also important in maintaining the ecosystems on which humans rely for many goods and services.

This assessment therefore highlights two key high-level points:

- » There are (poorly understood and quantified) costs to society when predation interfaces with human livelihoods.
- » There are also (poorly understood and quantified) costs to eliminating predation from many of our landscapes and ecosystems.

The interface between predation and human livelihoods, together with the consequences of individual acts or grouped common acts of predation are complex and changes to individual components of that interface may have unintended consequences. This

means that predicting the outcomes from specific policy interventions are difficult to make with any degree of confidence.

In complex situations relating to the natural environment and its components, adaptive management is commonly advocated as an important tool in the broader decision-making process. Science has a role to play in providing evidence which can inform policy at the interface of agriculture and the conservation of biodiversity, but this policy is also driven by other factors such as values and economic/financial conditions. Previous livestock predation management policy in South Africa has relied less on verifiable evidence and more on sentimental or financial considerations. The history of South Africa has resulted in a number of land-holding and management regimes (e.g. private, commercial vs communal subsistence farming) and policy needs to be relevant to all of them. Moreover the landscapes within which we currently function are considerably different from those of 300 years ago. This requires that consideration of both historic and present conditions are appropriately articulated for policy determination.

Historical understanding

An historical overview highlights the long, inconsistent, and vacillating past policies towards predation management in South Africa. These have oscillated between governance in the provinces and nationally, and have been led variously by individuals, interest groups and by the state. One consequence is that the policy environment is unclear, and there are conflicting and unresolved points of view. At no stage in the South African past has there been a single, coherent national policy environment providing guidance to provincial or local scale regulators or to industry operators with regard to the management of livestock predation.

This is relevant to future policymakers who need to provide consistency and clarity in policy and practice. In order to achieve this, detailed study is required because the wide variety of South Africa's environmental conditions means that a single policy cannot be applied equally to the various landscapes, physical and climatic, across the country. Any policy on predation management in South Africa is likely to benefit from accounting for both top-down and bottom-up drivers, determined on the basis of their ecological and socioeconomic rather than their administrative context. This might be done, for example, by considering bio- or eco-regions, rather than provincial or other political boundaries. Moreover, operational differences between subsistence and commercial farmers and between privately owned and communally managed land need to be accounted for and integrated into a flexible policy that is well-informed by the biological and agricultural sciences.

Socio-economic perspectives around livestock predation

As predation on livestock is ubiquitous in rangelands in which predators abound, the traditional response often includes a level of investment in predator control and/or stock protection in order to minimise economic losses. In the past, commercial farmers in South Africa received significant levels of government assistance in this regard in order to bolster an important economic sector. In general however, livestock farming has become increasingly difficult over time, as a consequence of declines in the relative prices of livestock products, increasing input costs, and decreasing government assistance. The

difficulties of stock farming have been exacerbated by a resurgence in predator numbers and by increased rates of predation. These are attributed, at least in part, to a reduction in co-ordinated control efforts by the state. Farmers now have to take individual decisions about how much to invest in predator control, and the choices will vary according to livestock types, the nature of land ownership, and cultural factors that include perceptions of predator behaviour and neighbour behaviour.

Approximately 38,500 commercial livestock farmers produce about half of South Africa's agricultural GDP (see estimates below) and provide about 245,000 jobs. The sector is dominated by small livestock (sheep and goats) in the western half of the country, and cattle in the east. Game farming occurs throughout the region, but particularly in the east and north. Some two million farmers operate in the communal rangeland areas. The communal areas tend to be heavily stocked, and contribute relatively little to market production, but contribute to food and cultural security. Sheep and goats have decreased to 68% and 72% of their 1980 numbers, respectively, while cattle numbers have remained relatively stable. Wildlife ranching has grown exponentially since the 1980s, assisted by the fact that landowners can acquire property rights over wildlife under defined legal conditions. Concomitantly, the number of employed farm workers has declined markedly with the consolidation of farm properties and the imposition of stricter labour laws. The decline in domestic stock husbandry and the need for less labour may well have contributed to the increased levels of poverty and inequality. On the other hand, the increasing financial challenges of farming of all kinds threaten to impede the successful establishment of emerging black farmers.

Until recently, there were few studies to quantify the rates of livestock predation. Older estimates are relatively unreliable, and while recent large scale surveys have been an improvement, they still typically rely on how a particular farmer judges the rate of predation and the species involved, and not on formal observation conducted in a scientific manner that can be replicated. It seems that there are many incentives for individual farmers to over-report livestock predation. Comparative data suggest that there are differences in rates of predation between small and large livestock on commercial farms. For example, reported rates of livestock loss to predation

are an order of magnitude higher on small stock than on large stock farms (provincial averages range from 3-13% vs 0.1-0.9%, respectively), and intermediate for a mixed sample including game farms (1.4-2.8%). There are no comparable studies from communal farming areas, but reported household losses are around of 0.5-19% of small stock and 8-11% of cattle.

Reported losses from predation also have to be considered in the light of other possible losses such as through poisoning, theft, disease and drought. In the communal farming areas in particular, these may result in significant loss of stock. Moreover, little attention is given to analysing what stock loss there might have been in the absence of predators, particularly as it is known that predators often target weaker animals. The reanalysis of data from a controlled study suggests that a reduction in predation losses could lead to approximately half that reduction in total losses, while the reanalysis of data from another controlled study even suggests that predation loss accounts for only half of total losses experienced by farmers. Further work is required to increase our understanding before these insights are used to formulate policy.

The presence of free-ranging predators in rangelands has two kinds of costs: viz the cost of taking action to reduce predator threats to livestock, and the losses of animals on account of predation. To date, we have little reliable knowledge about the cost of avoiding predation. We can, however, estimate that the gross production value in 2016 of free-ranging livestock in the country was c.R40 billion and yielded direct GDP value of c.R12.3 – R14.7 billion. Losses in the formal livestock sector (estimated to be approximately R3 billion annually) amount to about 7.5% of gross production value. Assuming that in the absence of predators about 50% of these animals would be lost to other causes (see above), the loss due to livestock predation amounts to about 0.5% of the Agriculture Forestry and Fishing Sector GDP and 0.01% of national GDP, or 0.02% if multiplier effects are included. Even if game losses and livestock predation losses in the small scale and subsistence sectors were taken into account, and if expenditures on predator control were included, the overall impacts would remain small when viewed in the context of the national economy. Nevertheless, these losses may be of local economic and social significance, particularly

in the arid areas of the Karoo and in certain communal rangeland areas. In areas where farming is marginal and households are poor, high levels of predation could have significant welfare impacts to the extent that they could also contribute to local levels of social disharmony.

In the future, any studies on livestock predation should include a strong social research element so that farmer motivations and responses when managing livestock and predation can be better understood. In addition, such research should consider the broader consequences on society as a whole. For instance, while yet unknown, it may be that the optimum solution for farmers could align with the optimum solution for the environment and society. It has been suggested that this alignment might occur through establishing 'predator-friendly' production systems that reduce risk by pursuing a more natural ecological balance, and returning management emphasis to stock protection, not predator eradication, measures. Such initiatives require understanding and addressing institutional, informational, financial and social obstacles to innovation of this kind. An alternative would be that appropriate policy instruments will need to be put in place that encourage farmers to engage in practices that benefit broader society.

Ethical principles

One of the key elements in the livestock predation issue is that it generates conflicts of interest between various stakeholders, and conflicts of interest have ethical implications. This means that guidelines, or policies, for resolving conflicts of interest are needed. Those responsible for policy need to examine competing interests and moral obligations as they seek the optimum outcomes, not only for all the different stakeholders, but also to find sufficient consensus between stakeholders once their interests have been taken into account. According to social contract theory, the laws or policies to be applied are those that rational agents would agree to and, in order to achieve this practically, a process of broad engagement and consultation will be necessary.

Policymakers, however, also need to bear in mind that not all stakeholders have an equal voice, and future generations of people have a stake in the choices that are made today. Moreover, there is an argument that non-human living entities, especially sentient animals, have interests in the avoidance of pain, hardship and death.

POLICYMAKERS

A variety of views exist in respect of human ethical obligations to other animals. Nonetheless, there is a broad consensus among ethicists, as well as among the general population, that cruelty towards non-human animals is not morally justifiable. Policy makers have therefore to justify, ethically, any action that may cause suffering or death. The welfare of individual non-human animals is not the only matter to be considered: the ecosystem itself, according to holists, can be harmed and that loss of range and habitat, climate change, pollution and other factors can lead to unethical extinctions and biodiversity loss.

Thus it is the responsibility of government to mediate between competing interests and to facilitate the formulation of clear, workable policy and even legislative reform, where necessary. In a constitutional state, there is an obligation to ensure that all stakeholders' interests are considered and that solutions are found that are fundamentally fair. This includes acknowledging that humans are responsible for human-predator conflict and therefore have a responsibility to seek solutions to it; adopting management methods that seek to be effective and to minimise unnecessary harm (to individual animals, species, the environment in general and to societal sensitivities and values) by utilising the best available evidence; and aiming to solve the problems in a manner that is affordable and where the costs are fairly distributed. The methods of predator management that are most suitable in terms of the social contract may not be practicable without the participation and intervention of the state and the use of state resources.

Legal perspectives

At present, there is no clear legal framework for the management and control of predators by landowners for either communal land or privately owned land across South Africa. Rather, there is a plethora of anachronistic and disconnected legislation and policy which can be difficult to access, is outdated, and has conflicts between local and national scales. The provincial nature conservation ordinances, formulated for pre-1994 South Africa under the previous dispensation, of the Cape, Orange Free State, Transvaal and Natal provinces, as well as some former homelands, still apply in some of the nine current provinces alongside the post-1994 national and provincial legislation.

This makes it difficult for regulators, law enforcement officials and livestock managers dealing with predators to know whether they are acting within the law.

By way of example, in the North West Province, the hunting regulations must be read in conjunction with the following legislation:

- » Nature Conservation Ordinance 12 of 1983 (Transvaal Province)
- » Bophuthatswana Nature Conservation Ordinance Act 3 of 1973
- » Nature and Environmental Conservation Ordinance 19 of 1974 (Cape Province)
- » National Environmental Management Biodiversity Act 10 of 2004

In addition, there are draft regulations and policies that may also be applicable (North West Extraordinary Gazette on 20 June 2013, Provincial Gazette No. 7121). These are:

- » Draft Norms and Standards for the Import, Export, Transport, Capture and Keeping of Birds in the North West Province.
- » Draft Guidelines for the Development of Protected Areas Management Plans in the North West Province.
- » Draft Alien Species Regulations for the North West Province.
- » Draft Amendments to the North West Fencing Policy.

Although the stated purpose of the draft Norms and Standards for the Management of Damage-Causing Animals in South Africa is to introduce a uniform approach to appropriate and effective interventions and the application of minimum standards, the current draft requires comprehensive revision in order to achieve this. The proposed permit system is administratively burdensome and impractical and for this reason runs the risk of livestock managers failing to comply. Approaches to policy that promote compliance are more likely to result in effective regulation of human interactions with stock predators. Attention therefore needs to be paid to developing mechanisms within these Norms and Standards to encourage compliance, particularly with the

National Environmental Management: Biodiversity Act 10 of 2004, and relevant provincial legislation relating to wild animals.

Management practices

Humans have employed a range of strategies to manage the cost of livestock losses they may incur from predators. While many have demonstrated some success in reducing livestock losses, the negative consequences of predation management have also been shown. Without predation management, the economic viability of livestock farms may be threatened and can adversely affect local and regional economies. The ideal outcome would be one that makes it possible to ensure a sustainable livestock industry and to promote biodiversity and ecosystem conservation, while being sensitive to important cultural norms relating to the specific area where predation management is applied.

Historically, efforts to control predation have seldom been tested in a rigorously scientific or appropriately adaptive manner, and we thus continue to work with a paucity of reliable evidence relating to the overall efficacy of the majority of these methods. Indeed, it is the absence of sufficient reliable evidence that means that we remain scientifically unable to support or refute any specific method.

An effective predation management method is widely understood to be context-specific and the applicability of any one method will vary depending on *inter alia* the targeted damage-causing species, the type of livestock operation, season, location, and environmental conditions. Effective predation management is likely to consist of a range of complementary methods/activities (including selective, humane lethal methods where necessary) and no single approach should be regarded as a “silver bullet solution” to the problem. There is a strong and urgent need for applied research of high scientific standards (i.e. randomised with repeats and controls) to better inform policy development around predation management. The development of any policy should include careful consideration of local conditions, the cultural context, ethical imperatives as well as the socio-economic position of the landowner(s) before any management intervention is prescribed or implemented.

Any management of a predator will rely on interventions about which we have imperfect knowledge.

Thus any intervention should be implemented in an adaptive manner. This requires collecting baseline information on predator biology, and ecology in the precise landscapes where they live e.g. nature reserves, commercial livestock farms, game farms and communal areas. Without baseline information of this kind, predator management activities will continue to be haphazard and probably ineffective at reducing livestock damage. It will also contribute little to developing policy for effectively managing these predators.

Principles that may assist policy makers include: a) Encouraging and supporting multi-sector collaborative research (e.g. scientists, wildlife managers, interest groups, farmers and government officials) to address important knowledge gaps, and b) promoting the use of an adaptive management framework that will allow for predator management in conjunction with collating baseline information and increasing a formal body of evidence relating to individual interventions and their outcomes. This may be best implemented through a joint venture in which both policy-focused and research-focused groups collaborate on a joint learning/research project.

Jackal and caracal as the leading role players

The effective management of any predator's risk to livestock requires a basic understanding of the predator's biology and ecology that assists in predicting its responses (at individual or population levels) to human intervention. Black-backed jackals and caracals are the dominant predators of livestock in southern Africa today, and are the primary cause of financial losses to the livestock production industry. Despite over 300 years of lethal management, people have been relatively unsuccessful in eliminating livestock losses caused by these two species. This may, in part, be due to the fact that predation management has focused on reducing mesopredator population size, with limited consideration of the ecology and biology of the target predator(s) (e.g. it has been shown that jackals and caracal can respond to persecution through compensatory immigration and reproduction). The fact that these mesopredators have been able to switch from wildlife to livestock predation is evidence of behavioural and ecological plasticity that has

enabled them to persist despite centuries of attempted population reduction by humans.

Despite their role as the dominant livestock predators in southern Africa for over 300 years, there has been relatively little research on the biology and ecology of these mesopredators. What is known has been biased towards the feeding ecology of the two species, with comparatively little information on social behaviour, activity patterns, reproduction, home range and habitat selection, dispersal, and population densities. Our knowledge is also spatially biased, focusing on limited areas (typically such research is focused in protected areas). Given the adaptability of these mesopredators, research needs to be replicated across several habitats and land uses to allow for more accurate predictions that incorporate spatial and temporal variability in their biology and ecology. Importantly, there is very little known about the size and trends in size over time, of the populations of black-backed jackal and caracal, even for relatively small regional sub-populations.

The role of the mesopredators

Ecological systems are complex, and such environments are composed of interconnected links in food chains. Due to their complexity, small alterations in these food chains can have important (and in many cases unpredictable) cascading effects on other organisms and thus on the ecosystem as a whole. The anthropogenic eradication of most apex predators across most of South Africa has created the opportunity for mesopredators to expand their ecological niche. Analogous to our knowledge of the individual species, we have a very limited understanding of the cascading effects of changing (elevated or reduced) numbers of mesopredators on co-occurring biodiversity. This limitation is, in part, a consequence of previous research being focused on larger charismatic species (for which the majority of funding is earmarked), with few or no multi-trophic investigations into the mesopredators and their primary prey species. This is further exacerbated by the limited basic ecological data available on the roles of many small mammals across South Africa.

Additionally, most of our insights into the important mechanisms that may mediate the impact (or lack thereof) of mesopredators, and the data that supports these insights, are derived from northern temperate

regions, oceanic islands and tropical rainforests. The local situation may be slightly or starkly different, but these mesopredators undoubtedly have an important role influencing regional and local biodiversity. Therefore, the only firm prediction that can be made is that management of these species can precipitate a broad spectrum, ecological effect. The policy implications are that, with so many unknowns hampering our ability to predict management outcomes (and therefore determine policy), it is unwise to prescribe an all-encompassing predictive directive for policy development.

It is further likely that ecosystem responses to management (i.e. policy) of mesopredators will vary among habitat types and biomes. Thus, what is potentially prescribed as effective for the Karoo landscape may not necessarily apply to the other biomes. Ecosystem level responses that result from mesopredator management are likely to be context dependent and will vary in their extent and intensity.

Other predators of livestock

Other than black-backed jackals and caracals, species responsible for livestock predation (generally less than 10% of such impacts) include leopards, lions, cheetahs, servals, African wild dogs, side-striped jackals, Cape foxes, free-roaming dogs (feral or managed), spotted hyenas, brown hyenas, honey badgers, bushpigs, chacma baboons, crocodiles, and various corvids and raptors. The relative significance of these predators varies locally.

Predation on livestock by predators other than black-backed jackals and caracals is influenced by a number of factors. They include intrinsic (habitat, home range, movement patterns, dispersal, social structure, activity patterns, density, habitat quality and prey species) and extrinsic factors (prey density, other predators, distance from water sources, distance from protected areas, elevation and surrounding vegetative cover) that vary for each predator species. The nature and extent of these factors, and how they can be used to manage livestock predation risk, is poorly known. There are also numerous gaps in our understanding of the economic importance of predation by most species.

There is no coordinated predator conflict monitoring across all provinces. A risk model of livestock predation by predators based on environmental and livestock management variables (or any other variables that can

be identified), which allows for identification of high-risk zones to define mitigation strategies needs to be developed, based on such a monitoring programme.

Predator research is predominantly carried out in formally protected areas. Thus, to better inform policy development, it is essential to increase research into non-protected or production landscapes. Furthermore, the main determinant of predator survival in non-protected areas is human-wildlife conflict and lack of tolerance of predators by livestock producers; it is essential that research address these issues. There is also a bias in research focus across species, such that some species (e.g. leopards) are relatively well studied while others (e.g. free-roaming dogs and side-striped jackals) are not. The focus of research therefore needs to be informed by the extent of the challenges presented by each species, not by their degree of charisma.

Way forward

It is clear from this assessment, summarised here, that astute political and scientific leadership is required effectively to develop, and then to apply, appropriate policy to manage the costs and conflicts arising from livestock predation in South Africa. As the first of its kind, this assessment has identified numerous gaps in our knowledge in relation to livestock predation, as well as highlighting the urgent need for the application of an adaptive management framework to better use and build on existing knowledge. This will require both a strategic national research programme to provide evidence for policy development, as well as closer cooperation between policy developers, livestock managers and researchers. Based on these insights, the much-needed adaptive management framework may be best implemented by employing a transdisciplinary approach where both policy-focused and research-focused groups work together with livestock managers throughout the process on a joint research project.

INTRODUCTION – THE NEED FOR, AND VALUE OF A SCIENTIFIC ASSESSMENT OF LIVESTOCK PREDATION IN SOUTH AFRICA

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INTRODUCTION

*For two millennia attempts have been made to prevent predation on livestock, but the problem is still with us. The arrival of domestic livestock in southern Africa about 2000 years ago (Pleurdeau et al., 2012) would have initiated a then novel form of human-wildlife conflict, this driven by the killing of livestock by indigenous predators, and attempts by pastoralists to protect their livestock. The archaeological record appears to be silent on how early pastoralists tried to protect their livestock, although Horsburgh (2008) identified many jackal *Canis mesomelas* remains in archaeological sites – could these represent retaliatory killings? More recently, early historical records from the 15th Century onwards (e.g. material in Skead, 2011) provide some hints. These include early descriptions of the use of dogs, herding of livestock, as well as retaliatory attacks on predators.*

LIVESTOCK predation in South Africa has been estimated to cause losses exceeding R1 billion annually (Van Niekerk, 2010). The costs are carried by individual livestock farmers, with cascading socio-economic effects across society (Kerley et al., 2017). Clearly this is a substantial problem, and ways to limit the costs and consequences of livestock predation are required. Modern pastoralists are faced with a particularly complex challenge, as they have to protect their livestock within a framework of economic, regulatory and societal restrictions, which reflect increasing awareness of how wild animals are treated and the need to conserve biodiversity (Kerley et al., 2017). Regulatory authorities, in developing effective policy and legislation, are constrained by the same pressures, as well as by the limited scientific information relevant to the drivers of livestock

predation, the efficacy of various management interventions and the consequences (unintended or otherwise) of these interventions for biodiversity and ecosystem process (e.g. Treve, Krofel & McManus, 2016). Predator management may have both perverse outcomes (e.g. Minnie, Gaylard & Kerley (2016) show earlier reproduction in managed jackal populations) and unexpected positive outcomes for biodiversity (e.g. Minnie, Kerley & Boshoff (2015) show that livestock are sometimes withdrawn from high risk areas, leading to a relaxation of domestic herbivore pressures).

Addressing the problem of livestock predation requires appropriate, robust, evidence-based information, accessible to both policy makers and livestock managers. There is a plethora of “research” undertaken on predator-livestock interactions, but not

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all of it represents robust science, directly relevant to the information needs of managers or policy makers. Furthermore, the relevant information is scattered and hard to access. The work has been focused on “commercial” farming areas, with few studies in areas where pastoralism is a communal undertaking. There are also many gaps in the research. Thus a need exists for a policy-relevant synthesis of the issues, and its distillation into an agreed-upon set of guiding statements useful to policy development. This information can also be used to identify gaps in our knowledge and hence guide research.

The process to produce such a synthesis is known as a scientific assessment (Scholes, Schreiner & Snyman-van der Walt, 2017), and is an increasingly relied-upon

approach to tackle complex problems (see below). The need for such an assessment was identified by industry role players and the relevant government departments, based upon the scale and complexity of the livestock predation issues in South Africa. A diverse team with technical expertise in the fields of biology, economics, ethics, law and humanities was assembled to conduct the assessment. The team followed a rigorous process to collate and interrogate available knowledge regarding livestock predation, relying on their collective expertise and that of a large number of independent reviewers. The document which follows is a global first in terms of the generation of a policy-relevant synthesis on livestock predation.

Box 1.1 Defining livestock

The term livestock generally refers to animals that are managed for food or fibre production or to serve as draught animals. Although typically (Thompson, 1995) applied to conventional agricultural settings and domesticated animals (e.g. cattle, sheep, pigs, horses), the term can be extended to cover a diversity of taxa such as fenced wildlife, fish, managed game birds such as pheasants, or even silk moths. The objectives of their management can extend to the provision of sport or satisfying cultural requirements.

For the purposes of this assessment, livestock are broadly defined as comprising domesticated animals and wildlife (the former excluding poultry, and the latter including ostrich *Struthio camelus*) managed for commercial purposes or human benefit in free ranging (or semi-free ranging) circumstances that render them vulnerable to predation (Kerley *et al.*, 2017).

WHAT IS A SCIENTIFIC ASSESSMENT?

The nature of the decisions which need to be made by society range from those that are primarily value driven (e.g. whether to legalise the death penalty) to those that are largely technical (e.g. regulation of the use of radio wave frequencies); from decisions that are inherently simple with a high level of insight into the important factors (although they may involve complicated procedures; e.g. trade agreements between countries) to decisions that are complex with a high level of uncertainty regarding the outcome of different interventions (e.g. decisions around the conservation of natural resources or climate change). The expertise of scientists is commonly harnessed to inform these

societal decisions and the input is conventionally made through “expert reports” or “scientific reviews” (Scholes *et al.*, 2017).

It is only over the past few decades that the task of informing decisions on much more complex issues (e.g. see Cilliers *et al.*, (2013) where they explain complex or “wicked” problems, as distinct from technically complicated matters without social ambiguity) has been seriously engaged by experts. These involve choices for which there is no clear technical solution, around which there is commonly disagreement on how best to intervene, and where there is a high level of societal interest in the outcome. Tackling problems and decisions of this nature has highlighted weaknesses in the traditional approaches of science informing

decisions. These weaknesses became clear towards the end of the 20th century when solutions were being sought to deal with the increasing “hole” in the ozone layer (World Meteorological Organization, 1985). Out of this process emerged what may be considered to be the first “scientific assessment”. The approach taken was very different to that of expert reports and scientific reviews in a number of respects which are expanded on in this chapter. It has also subsequently been further developed with the establishment of the International Panel on Climate Change to inform decisions on climate change responses, as well as the Millennium Ecosystem Assessment which sought to address the problems of biodiversity loss and ecological degradation (Scholes *et al.*, 2017).

What is it that distinguishes a scientific assessment from the more traditional report or review? What are the specific characteristics of a scientific assessment? When is it appropriate to invoke the methodology of a scientific assessment? What are the procedures to follow? The concept of a scientific assessment continues to evolve. There is no universally-agreed definition and set of procedures for conducting such an assessment, but there are a set of core principles which are widely accepted (Mach & Field, 2017). A useful summary synthesis of the history and the essential elements of a scientific assessment, and how it has been changing over the past three decades, is presented by Scholes *et al.* (2017). Core to this understanding are three elements; context, process and governance. The context is dealt with below, while process and governance are dealt with in more detail in the next section.

Context

Management in the context of complexity, change and uncertainty must be adaptive. Those taking decisions must regularly review the problems that they are addressing and the extent to which their interventions are succeeding. Where the desired responses are not being achieved, the review process should lead to different decisions followed at a suitable period by further review. The record of evidence, the logic underpinning a decision, and the outcome must be explicit. In the realm of natural resource management this is known as “adaptive management” (Norton, 2005), more generally (in the social sciences, for instance), this is known as reflexivity.

The review process commonly requires a science-based assessment. The input from the assessment can be unidirectional, in which information and insights are contributed to an end-user by the “expert” or scientist or it can be more interactive in which there is a two-way flow of information between stakeholder, including scientists, with the joint generation of new perspectives through dialogue (an approach known as co-generation or co-production). Which approach to take depends on the nature of the questions being asked and the level of engagement of stakeholders. There are many instances where it is entirely appropriate to seek a simple expert opinion or to review in a unidirectional manner. This is often the most cost effective way to review and inform straightforward decisions (Table 1.1). Where the question is of high societal interest and contention, and where the technical aspects of the issues are complex, a two-way flow of information, in which the technical aspects of the specialists are integrated with other societal considerations such as value, culture, resource availability etc., is more likely to result in a robust and widely accepted outcome. It is in these circumstances that a “scientific assessment” is a suitable approach to informing decision making. Scientific assessments are also more suited to deal with multi-disciplinary issues, including those that involve very different worldviews and conceptual bases (a domain known as transdisciplinarity). Scientific assessments, on the whole, do not include undertaking original research. Rather they rely on existing literature which may be peer reviewed but need not necessarily be so.

History of this assessment

The Centre for African Conservation Ecology at the Nelson Mandela University (previously Nelson Mandela Metropolitan University) has conducted research focused on the small livestock industry and the environment since 1992. Within this broad theme, focus on providing sound, scientifically-based perspectives to industry and to policy makers relating to the mitigation of problems caused by predation on stock and specifically jackal and caracal was identified as a priority. Integral to the success of such a research programme was the buy-in and support of the key stakeholders. In this case the key stakeholders were the red meat producers, the wool and mohair growers and the relevant regulatory and policy departments of Government i.e. the Department

Table 1.1. Broad assessment types with their attributes, target audiences, processes and anticipated outcomes (Modified from Scholes et al., 2017).

Assessment type	Attributes
Expert report	Typically an expert report is aimed at a client and is governed by an agreement. There is/are specific questions to be addressed and the process is conducted over a few weeks or months by a selected individual or team. They may be reviewed by other, not necessarily independent, experts and the methodology used need not be explicit. Expert reports are used for technical but uncontroversial topics and they often make clear recommendations.
Scientific review	Scientific reviews are aimed at scientific specialists who are assumed to understand the technical terminology and will form their own judgements. The questions addressed arise from the science community, and are usually restricted to a single issue which is treated exhaustively. Scientific reviews are conducted by one to a few specialists over a year or so and are rigorously peer reviewed, typically by three independent and anonymous reviewers. They are governed by implicit scientific norms of fair attribution and measured language and explicit personal opinions are discouraged, although they may be tacit. Scientific reviews are appropriate to cutting edge research.
Scientific assessment	A scientific assessment is aimed at decision makers (stakeholders) in society assumed to be intelligent but not necessarily technical experts. The questions are posed by the stakeholders. The language used aims to be free of technical terminology but with use of summary tables and explanatory diagrams. There is a governance structure to establish legitimacy and credibility and a scientific assessment is conducted by a large and diverse team of experts. Subjective expert judgements are often required, but they are made explicit, along with statements of confidence. They are independently reviewed by other experts and by stakeholders, often amounting to large numbers of documented comments and responses which are placed in the public domain. The process typically takes 18 to 36 months, following an extended period of organization and is appropriate to problems which are both technically complex and socially contested. The output is policy relevant but should not be policy prescriptive.

of Agriculture, Forestry and Fisheries (DAFF) and the Department of Environmental Affairs (DEA).

In 2008 DEA embarked on a path of strengthening the evidence basis for policy setting and evaluation. This led to a "Research, Development and Evidence Framework" (RD&E framework) being published in 2012 (Department of Environmental Affairs, 2012; von der Heyden, Lukey, Celliers, Prochazka & Lombard, 2016). A key driver behind the development of this framework was the need to better set targets and to identify more appropriate evidence portfolios for the performance outcomes that

the President requires members of his cabinet to agree to, and to be measured against. Of the twelve high level performance outcomes, *Outcome 10* relates to the protection and enhancement of environmental assets and natural resources. In developing the RD&E framework, three aspects of evidence-based approaches to policy and performance monitoring were identified. Briefly these are i) appropriate data and factual information, ii) suitably analytical reasoning to contextualise the facts and iii) structured stakeholder commentary and opinion on the issue under consideration. It was in this

setting that the initiation of a Scientific Assessment was identified as an appropriate approach to the livestock and predation issue. The RD& E framework has subsequently taken on a greater significance within the Department of Environmental Affairs with the publishing of the report *Evidence and policy in South Africa's Department of Environmental Affairs* (Wills et al., 2016) and the adoption of the National Biodiversity Research and Evidence Strategy – 2015 to 2025 (Department of Environmental Affairs, 2016).

Critical attributes of a scientific assessment

Considering assessments more broadly, Ash et al. (2010) argue that there are three qualities of an assessment that are necessary, although not sufficient, for the assessment to be successful. The three qualities are *legitimacy*, *saliency* and *credibility*.

Legitimacy is important to reduce the chances of the findings of the assessment being ignored by relevant stakeholders such as industry, communal farmers or policy makers. For an assessment to have legitimacy implies that a formal need for the assessment has been recognized by a mandated institution. Legitimacy establishes an “authorizing environment”. For an assessment to claim legitimacy also requires that it is perceived to have been conducted through an unbiased process which deals appropriately with the values, perspectives and concerns of the society for which it is being conducted. For this reason it is important that an assessment is inclusive of a range of stakeholders, institutions, disciplines and viewpoints. It is important to be able to *demonstrate* the fairness and inclusion – this is commonly achieved through a formal and recognized governance structure which ensures adherence to a set of pre-determined rules that regulate the process.

Saliency relates to the focus of the questions that are addressed by the assessment. It is important that the pertinent questions (and only these questions), as posed by the stakeholders, are answered. This implies that it is not appropriate to deviate into what the individuals who are conducting the assessment think is interesting or to allow new questions to emerge during the assessment without full engagement with stakeholders. This means that assessments represent the questions

considered salient at the time: substantive new research and changing social circumstances would require a new assessment.

Credibility refers to the standards of scientific and technical rigour that are apparent through the assessment process. For this reason it is important that the individuals involved are individually recognised for their expertise in the field and their independence – not as representatives of an institution or philosophy. Equally, it is important that there is a rigorous, broad and transparent peer review process that critically considers both the factual information and the logical flow of the assessment. In this regard it is critically important for reviewers to comment on the traceability of assertions to primary sources or flagging them as “conjecture” or “expert judgment”. For these reasons the credibility and experience of the assessment leader and management team is an important factor in delivering a high quality of work on large and complex assessments.

THE PREDSA PROCESS AND GOVERNANCE

From the section above we understand that a scientific assessment is a product that is useful to decision-makers operating in the public arena, dealing with complex technical issues involving stakeholders with differing views and expectations. For this reason it is important that the assessment has legitimacy. Much of the legitimacy is established through process and governance. This section deals with the process and governance of the scientific assessment of livestock predation and its management in South Africa (PredSA); it is descriptive of the specific approach taken in this assessment, but see Scholes et al. (2017) for a more wide ranging discussion of the topics.

Governance and process

The PredSA unfolded over four phases (Figure 1.1). There were two key aspects to the first phase, Phase 1, which involved both the establishment of a broad mandate (i.e. an assessment of the impact of predation on livestock in South Africa) and the securing of the funding to enable the assessment to be financed. In this process the Department of Environmental Affairs as the custodian and regulator of national biodiversity, as well

as the Department of Agriculture, Forestry and Fisheries as the regulator of national agricultural production were approached with a proposal detailing the potential for a Scientific Assessment of the form established by the Elephant Management Assessment (Scholes & Mennell, 2008). Concurrently the “producers” or “industry” (these include the National Wool Growers Association, Cape Wools, the Red Meat Producers Organisation), through their representative organisations and liaison forums (e.g. the Predator Management Forum) were approached as they are the bodies who manage both livestock, and indirectly biodiversity, on the ground and are most directly affected by policy and regulation affecting predation, livestock and biodiversity.

As the proposal had not originated within government or industry, it was important to ensure that there was real support for the idea of a scientific assessment on predation and livestock nationally, i.e. that the proposal had legitimacy. The measure used to gauge this support was the commitment of funding to the assessment. With a total budget in the region of R2,000,000, the process of gaining support and commitment as well as signing the agreements with Nelson Mandela University took approximately four years.

Phase 2 involved the recruitment of staff to manage the assessment, the establishment of the appropriate governance structures and processes, the development of databases, the development of a website (<http://predsa.mandela.ac.za/>) and the public launch of the assessment. A small management team, led by Graham Kerley with a project manager and an assistant and input from Bob Scholes and Greg Schreiner (who led the assessment on shale gas in the Karoo), drafted a PredSA process document – essentially the governance rules of the assessment (these rules pertained to mandate, decision making procedures, meetings etc.), which was designed to ensure that fair process was followed and that legitimacy of the assessment was thus enhanced. A key component of the governance was the establishment of a Process Custodian Group (PCG; Figure 1.2). The role of the PCG was to serve as an independent oversight body to ensure that the assessment was perceived to have been implemented in an unbiased manner, with procedural fairness and which considered appropriate values, concerns and perspectives of different actors.

The PCG members were not asked to comment on the *content* of the assessment, only on the *process* by which it was conducted. To this end their specific responsibilities were to provide feedback to the Project

Leader regarding the following:

- » Has the assessment process followed the pre-agreed guidelines?
- » Do the proposed author teams have the necessary expertise, range of perspectives and show balance?
- » Does the assessment, as indicated by the Zero order Draft (i.e. the expanded outline of the table of contents) cover the material issues expected by the primary stakeholders of such an assessment?
- » Are the identified expert reviewers independent, qualified and balanced?
- » Have the review comments received from the expert and stakeholder reviewers been adequately addressed and have the responses been adequately documented?

In order to achieve this mandate, the composition and affiliation of the PCG members was important. A six-person PCG was selected; each appointed in their own right and for their own expertise and judgement, but to ensure appropriate representivity, there was one representative from each of:

- » The Department of Environmental Affairs (selected by the department);
- » The Department of Agriculture, Forestry and Fisheries (selected by the department);
- » The National Wool Growers Association (selected by the Predator Management Forum);
- » South African Mohair Growers Association (selected by the Predator Management Forum);
- » SANParks, representing the research community;
- » The Wilderness Foundation Africa, representing NGOs and civil society.

There was an independent Chairperson from senior management at Nelson Mandela University in order to prevent conflicts of interest arising through a member who could be perceived as being part of a stakeholder group chairing the PCG.

Because of the need for both saliency and credibility, a multistep process was followed (see Scholes *et al.*, 2017 and Figure 1.3). The management team workshopped the first draft of the structure of the assessment as well as appropriate experts to serve as potential lead authors,

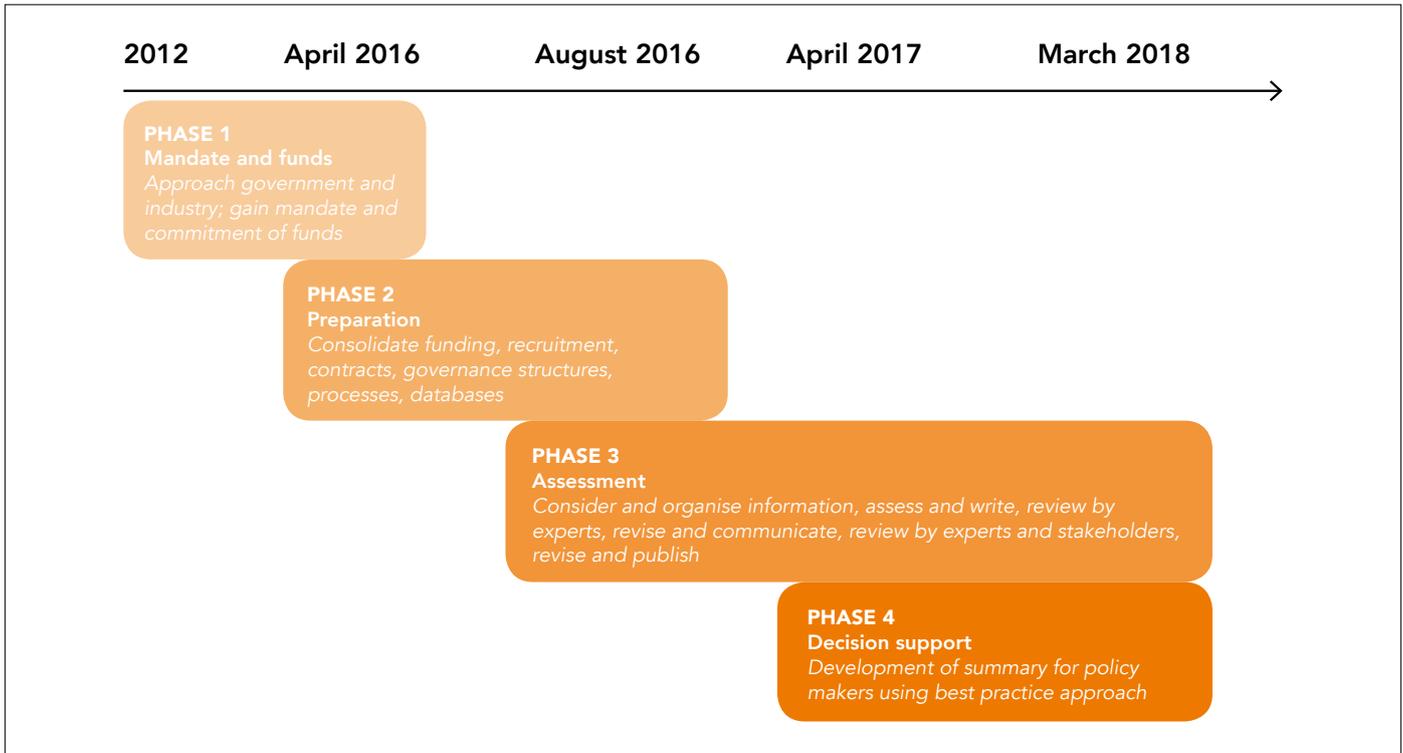


Figure 1.1. The four phases of the Scientific Assessment of Livestock Predation in South Africa.

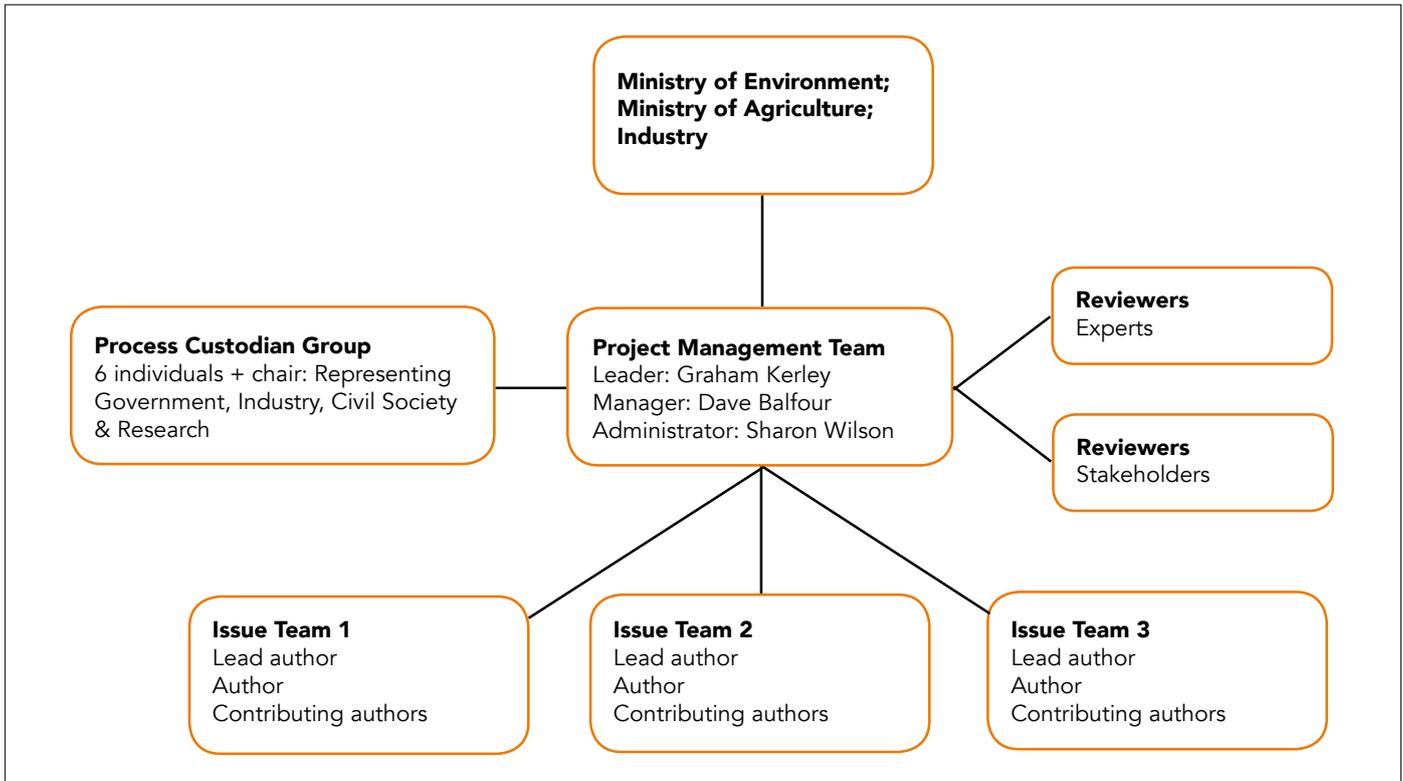


Figure 1.2. The governance structure for the Scientific Assessment of Livestock Predation in South Africa.

authors and or reviewers. From this list a final selection of preferred Lead Authors was chosen for their established expertise. In this selection attempts were made to favour younger individuals as there is evidence that participation in an assessment was beneficial to younger people (Scholes *et al.*, 2017). A brief bio-sketch was developed for each of the Lead Authors.

Following the establishment of the PCG, a draft structure of the final assessment, detailing the specific issues to be addressed (in chapter form) together with proposed Lead Authors i.e. the experts, was presented to the PCG, together with the full list of potential Lead Authors, for a “statement of no objection” in terms of the criteria that they had been mandated to use to evaluate the stages of the assessment. No objection was received for the Lead Authors but the management team was strongly encouraged to seek opportunities to ensure greater representation of black and female authors. This was done. Having established who the lead writing individuals were, the next step was to hold the Lead Author workshop (Figure 1.3). The purpose of this workshop was to introduce Lead Authors to each other and to begin to flesh out the structure of the document. The interactive process served well to gain the buy-in and sense of common purpose of the writing team.

This was followed by a process of each Lead Author identifying and inviting Authors for their chapter and entering into a four month writing period. At the end of the writing period, the entire writing team was invited to a workshop to present and receive commentary from the other members of the larger writing team. In this process the final structure of the document was agreed on and gaps and duplicated effort were identified and resolved. After a further six week writing period the First Order Draft (FOD) was submitted to the expert reviewers. Three reviewers were identified for each chapter and where possible one of them was international. Review comments were processed and the comments together with the responses were fully documented and made available on the website for scrutiny. This level of transparency is seen as being an important element of maintaining legitimacy. This was followed by a set of public announcements in both the industry forums as well as the public press that the Second Order Draft (SOD) was available for comment – the stakeholder review process, in which the FOD expert reviewers were encouraged to participate as well, to ensure that their comments on the FOD had

been adequately addressed. The open availability of the SOD lasted five weeks.

The processing of the comments from the stakeholder review process was managed in the same manner as for the FOD and was followed by the final author workshop resulting in the Final Draft of the assessment. This, together with a Summary for Policy Makers, was presented to the PCG for final sign-off on the process. Following this the manuscript was copy edited and submitted for publication. The Summary for Policy Makers was drafted by the Project Leader and the Project Manager together with the Lead Authors.

STRUCTURE OF THE ASSESSMENT

Chapter 1 introduces the problem, scientific assessments and the approach to this specific assessment. Chapter 2 deals with the historical context of the conflict between land users and predators in South Africa highlighting variability in our spatial understanding of the phenomenon, as well as how perceptions have changed over time. Chapter 3 deals with the current state of knowledge regarding estimates of the size and nature of the impacts of predation on livestock and highlights areas where we have very poor formal knowledge such as in communal rangelands. Chapter 4 deals with the ethical considerations in the management of livestock predator impacts. Chapter 5 explores the legal context of managing predator livestock impacts. Chapter 6 reviews the past and current predator and predation management practices, both in South Africa as well as internationally. Chapter 7 deals with the two most abundant predators that impact on small livestock farmers – the jackal and the caracal. Chapter 8 deals with the impacts of altering the density and ecology of meso-predators on the biodiversity of the rangeland ecosystems where most livestock are farmed in South Africa, and Chapter 9 deals with the role and impact of predators other than caracal and jackal. In addition a Summary for Policymakers is provided.

EMERGENT ISSUES

Although this scientific assessment is focused on the compilation of policy-relevant information, it is also important to recognise the value of issues that emerge through the process (Kerley *et al.*, 2017). Examples include the need for robust decision-making and management

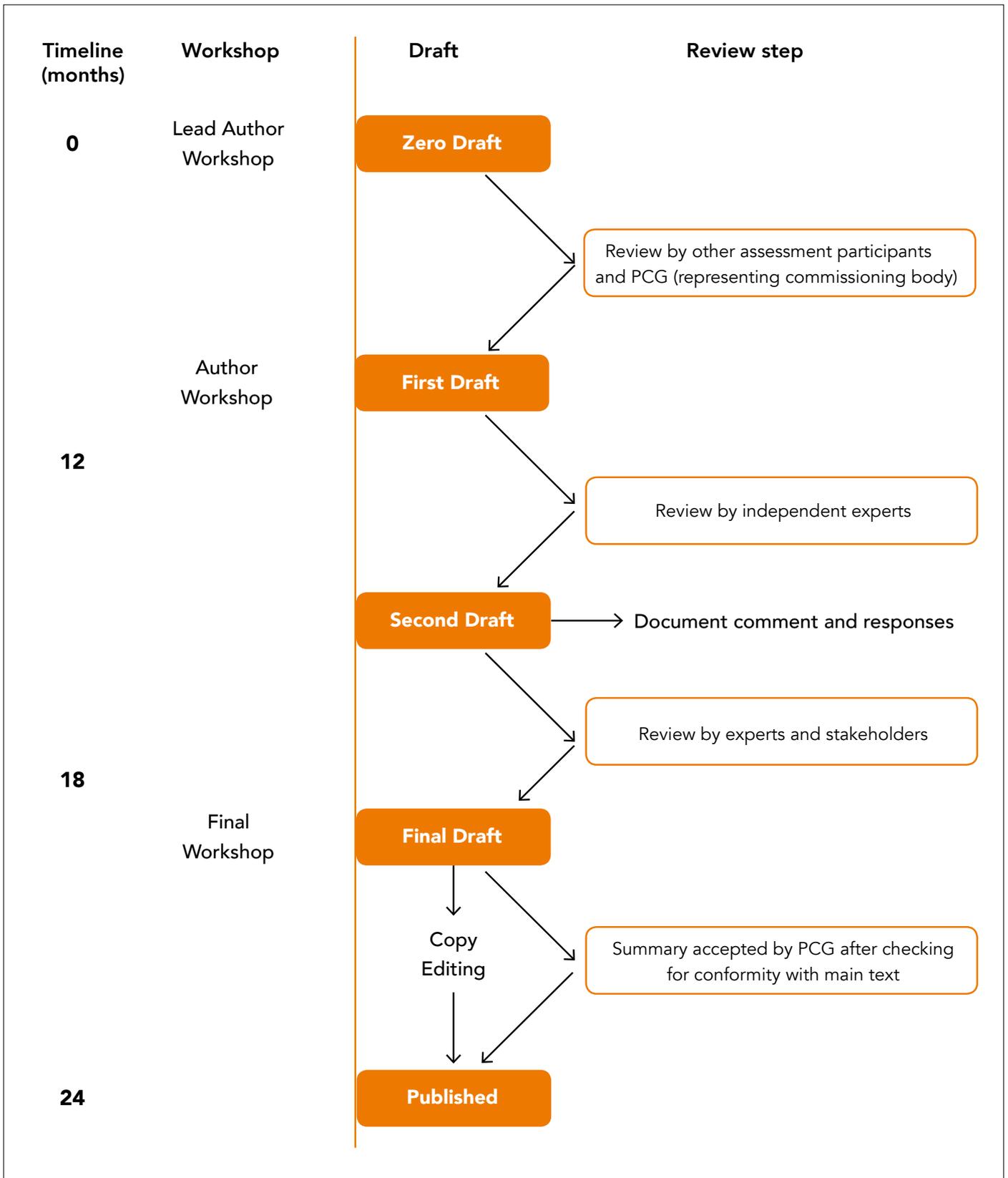


Figure 1.3. The timeline and process undertaken for the Scientific Assessment of Livestock Predation in South Africa.

approaches, recognising that the understanding of the livestock predation issue reflects the baseline that may alter over time (so-called shifting baselines (Pauly, 1995)), and the paucity of, but clear need for, research on the nature of livestock predation in communal rangelands. These issues are briefly described below.

Adaptive management

Decision making around complex issues is not a simple task, and can be seen to have two fundamental components. These comprise identifying and involving appropriate stakeholders, and the basis for the decisions and how their outcomes are assessed. These components are clearly intertwined, as for example it is important that stakeholders that will be affected by the outcomes of management interventions are able to participate in the decision-making in an informed manner with regards to the knowledge-base, objectives and possible (and eventual) outcomes of these decisions (Biggs *et al.*, 2008). Within the livestock predation environment, the set of stakeholders is diverse, and ranges from farm workers, farmers, provincial and national government authorities tasked with dealing with biodiversity management and agriculture, legal authorities, and civil society elements interested in issues as diverse as workers' rights and animal rights. A poorly recognised but increasingly important group are eco-tourists, as they provide one of the justifications for the re-introduction of apex predators (e.g. Hayward *et al.*, 2007). Their responses to livestock predation management interventions may have significant economic repercussions, and as a group they are very familiar with the power of social media. In this respect, the stakeholder challenges around livestock predation closely mirror those of elephant management (see Biggs *et al.*, 2008). Important distinctions are that elephant management is largely single species focused, relatively constrained geographically (there are less than 100 elephant populations in South Africa) and the processes to address the complexity around elephant management are well advanced (Scholes & Mennel, 2008). In this respect, elephant management serves as a powerful heuristic model for South African society to address the stakeholder issues around livestock predation. A further link between these two complex issues is the process of Strategic Adaptive Management developed by South African National Parks (SANParks),

as a tool to address complex issues, including *inter alia* elephant management (Roux & Foxcroft, 2011).

Adaptive Management as a concept for approaching complex issues emerged from the recognition of the need for a systematic approach that was based on robust information and which led to predictable outcomes. The principles were first formulated by Taylor (1911), considered to be the father of industrial engineering, and developed for the ecological context by Holling (1978). More recently SANParks has refined and developed the approach with the aim of achieving strategic conservation objectives, hence the term used within SANParks of "Strategic Adaptive Management" (see Roux & Foxcroft, 2011, and other papers in the 2011 special issue of *Koedoe* Vol 53(2) - <http://www.koedoe.co.za/index.php/koedoe/issue/view/82>). A key principle of adaptive management is "learning by doing". Where adaptive management differs from other approaches espousing this approach, is that in adaptive management the problem is formulated as a hypothesis, from which (multiple) testable predictions arise, and that management interventions should reflect tests of these predictions. Failure of management interventions suggests that the original hypothesis does not adequately describe system behaviour and needs to be revised as per the lessons from these interventions (Roux & Foxcroft, 2011). In this respect, adaptive management has been referred to as management by hypothesis, and management actions can be interpreted as experiments to test our system understanding. Thus, documented monitoring of outcomes is an essential feature of adaptive management. Adaptive management can therefore be seen as a feedback learning loop (Figure 1.4). Importantly, the full suite of stakeholders can learn through this process, not just about an agreed upon understanding of how the system behaves, but also from the lessons learnt as adaptive management is applied. This process can therefore be expected to have the added benefit of providing common ground for stakeholders and a maturation of all stakeholders' understanding of the system. This can be expected to reduce tensions between stakeholders.

The relevance of the application of adaptive management to the field of livestock predation is clear, but to date little attention has been paid to undertaking this formally. The strategic objectives of stakeholders

can be articulated in terms of the reduction in the conflict and a decline in livestock predation. Clearly, and as demonstrated in this Scientific Assessment, the system is complex, and there may be unforeseen or perverse outcomes of management interventions (e.g. Minnie *et al.*, 2016). The PredSA assessment identifies many management approaches to mitigating livestock predation. There is evidence that some of these approaches are less successful than others (Chapter 6). The challenge is for the policy makers, managers and other stakeholders to develop a shared set of strategic objectives and formulate a set of interventions that can be expected to allow us to move towards these objectives, and away from those demonstrated to have failed. Clearly, resources will need to be set aside to drive this approach, as well as to monitor and evaluate the outcomes, and to pass on the lessons learned. In essence, this assessment and the resulting policy shifts serve as components in an adaptive cycle and should be seen as such. The understanding generated through this

assessment is part of a progressive and adaptive process aiming to improve the management of predation and livestock in South Africa.

Shifting baselines and lifting baselines

The situation with regard to the nature and extent of livestock predation, the identity of the key predators and appropriate management responses is not static. The large scale eradication of the apex predators in the 18th and 19th centuries (Boshoff, Landman & Kerley, 2016) largely relieved livestock owners of concerns around lions *Panthera leo*, spotted hyenas *Crocuta crocuta* and African wild dogs *Lycaon pictus* over much of South Africa. Prior to this, written accounts were largely dominated by concerns of attacks by lions on livestock (and people), as summarised in Skead (2007; 2011) and Boshoff & Kerley (2013). Bearing in mind that transport of people and goods was dependent on the availability of draught animals, such attacks could leave

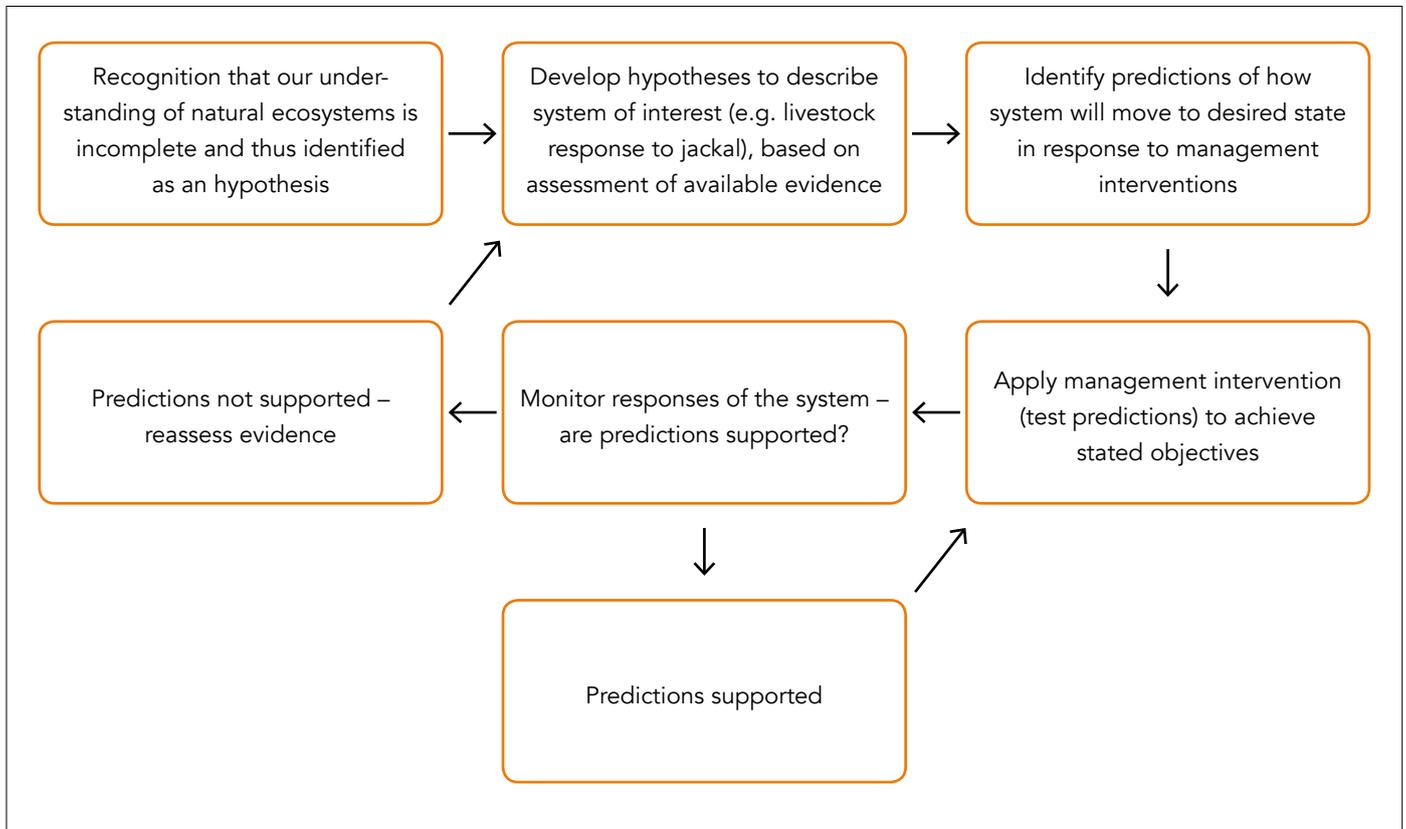


Figure 1.4. A simplified schematic of adaptive management, with the definition of the “desired state” reflecting the strategic objectives of system management.

travellers stranded. Responses to these threats include 19th century travellers' wagons being driven at night, when it was hoped that the noise of the party (whips cracking, shouts of the drovers) would deter lions from attacking (Boshoff & Kerley, 2013). Writings of the time are also replete with accounts of determined attacks on lions and other apex predators by livestock owners who seemed focused on killing all large predators. In contrast, these same writings rarely mention concerns of jackal attacks on livestock, and jackal killing seems to be more focused on collecting skins for making "karosses" (but see descriptions of KhoiSan concerns around jackal-predation of their sheep mentioned in the Van Riebeck diaries in the 17th Century (Skead, 2011)). Similarly, the caracal hardly features in 17th to 19th Century accounts.

Lions were progressively eradicated from the present-day Western Cape, Free State and Eastern Cape provinces by 1838, 1870 and 1879, respectively (Skead, 2007; Skead, 2011; Boshoff & Kerley, 2013). Thus, many generations of livestock farmers have since been operating under the "shifted baseline" (*sensu* Pauly, 1995) of jackal and caracal being the focus of their concerns (du Plessis, Avenant & de Waal, 2015). Memories of a different suite of predators have thus largely been lost. However, recently large predators have been re-introduced into areas from which they had been eradicated (e.g. Hayward *et al.*, 2007), for both conservation and ecotourism objectives. Inevitably, these re-introductions lead to escapes into neighbouring pastoral areas. Banasiak (2017) identified at least 75 conflict events arising from such escapes in the Eastern Cape Province since the 1990s, with livestock at the centre of most of these events (see also Chapter 9). So, while re-introductions of large carnivores may meet conservation and economic objectives, it is also important to recognise that some stakeholders may bear the brunt of unintended consequences. Typically these stakeholders see such emerging conflicts as due to "invaders", forgetting that the presence of these large predators used to be the norm (Roman, Dunphy-Daly, Johnston & Read, 2015). This reflects a need to "lift the baselines" and to educate these stakeholders as to the fact that the presence of these large predators is the pre-colonial norm under which these ecosystems evolved, as well as to the broader value of such conservation outcomes, and to promote investment in mechanisms to reduce these conflicts if we are to continue to celebrate such conservation successes.

Addressing livestock predation in communal farming areas

Conflict over livestock predation can be expected to occur wherever livestock are exposed to predators. Early on in the PredSA process, the bias towards studies of livestock predation in so-called commercial farming areas was recognised, with a dearth of studies in the South African formal literature relating to communal farming areas. The background to this pattern is beyond the scope of this assessment, but it is important to recognise this bias in attempts to gather policy-relevant information. It was also clear that simply recording a gap in information would be deeply unsatisfactory. This because there are clearly many people in South Africa who have good knowledge of the issue – it is simply not recorded. To address the matter, PredSA partnered with an NGO, Conservation South Africa, who currently have established programmes in the rural and communal farming areas of the Northern Cape, Eastern Cape and in Mpumalanga and are working with communal rangeland farmers on matters to do with livestock and biodiversity. Together a questionnaire survey was developed and over 270 people were interviewed across the three areas using the established forums and in the local vernacular. This process was run in parallel with the drafting of the Second Order Draft and the results and the findings are incorporated into the relevant chapters (Hawkins & Muller, 2017). The reviewers of the affected chapters were approached for comment on the additional material so as to ensure that there was no shortcutting of due process. Thus, although collecting novel data is not the norm for a Scientific Assessment (Scholes *et al.* 2017), this innovation is seen as being an enriching contribution to a uniquely South African situation, and as being consistent with the approach being taken by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) process when incorporating Indigenous and Local Knowledge into an Assessment (Sutherland *et al.*, 2013; IPBES, 2016).

WAY FORWARD

The PredSA is a significant step forward for South African society to address the conflicts and costs of livestock predation. We know of no precedent worldwide. Replicating this approach in other nations will represent a powerful approach to reduce global levels of conflict between predators and livestock owners.

This document represents a compilation by a group of experts of what we know and what we don't know and, to some extent, what we need to know about livestock predation. It is compiled by experts, largely for an informed audience. The material contained in this assessment is aimed at both livestock managers and those with an interest in biodiversity management in South Africa as well as policy makers. Given the cultural and linguistic diversity of livestock managers in South Africa, this document, although currently only available in English, should also be made available in multiple languages. The opportunity also exists to communicate the information in the form of "extension documents" that can be made available to livestock managers, extension officers and other stakeholders. The power of modern multimedia (video and audio) can also be harnessed to make this information more broadly available.

This PredSA assessment should not be seen as the final step in addressing this issue. By their very nature, scientific assessments are living processes, and should catalyse the further generation of knowledge, whether through stimulation of strategic research activities (e.g. research on livestock predation in communal areas highlighted above) or lessons learnt from adaptive management. This will by definition make it necessary to revise and update scientific assessments on a regular basis, as is done for the climate and biodiversity/ecosystem services assessments (IPCC, 2013; IPBES, 2016). In this respect, the record of the process in developing the PredSA assessment allows for the process to be replicated by future generations of assessment practitioners, and this document provides the foundation for an ongoing learning process that will hopefully lead to a reduction in conflict around livestock predation in South Africa.

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HISTORY OF PREDATOR-STOCK CONFLICT IN SOUTH AFRICA

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INTRODUCTION

This chapter provides an historical account of the longer-term predator-livestock interaction within what is now the Republic of South Africa, against an abbreviated summary of socio-political and economic changes. Our arrangement is chronological, and the methodology is that of the humanities and social sciences by way of utilising existing primary and secondary sources to construct a coherent, explanatory narrative. This is an assessment of currently available published knowledge, which has its limitations, and we have not conducted in-depth primary archival and other research for this purpose.

ALTHOUGH the interface between pastoralists and predators has a long history in southern Africa (indeed, across the world), the background against which this has occurred has evolved over time. A motivation for this chapter, therefore, is to analyse the documentation relating to predation and livestock in the wider complex and regional political history of the country. When human and livestock population numbers in the subcontinent were low, the frontier open, and farms unfenced, predator management by pre-colonial people and early colonial settlers was informal and without regulation by the state. With the rise of effective colonial government, particularly in the Cape Colony in the mid-nineteenth century, the closing of the frontier with fenced farms and the invasion by settlers into the highveld interior, the state began to assist white farmers with predator control.

The value of agricultural products to colonial society,

especially woolled sheep, motivated government to support and subsidise 'progressive', or commercially productive, farmers who promoted the local economy through the export of wool. Despite variations over the decades in the price of fleece, state assistance to white farmers to counteract damage-causing animals continued into the twentieth century, declining only with liberalisation of government agricultural policy from the 1980s and the transition to democracy in the 1990s. Waning government support mirrored the dwindling contribution of the agricultural sector as a proportion of South Africa's GDP from 21% in 1911 to 2.4% a century later. Between 1946 and 2011, the economic contribution of sheep farming to the overall economy by way of wool, lamb and mutton declined from 17% of gross agricultural output to 3.7%. Real mutton and wool prices in 2011 were almost at the same level as they had been in 1911. Moreover, the number of commercial farms in South Africa has generally declined: from a

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highpoint of 112,453 in 1946 to 39,966 in 2007 (Nattrass & Conradie, 2015; Nattrass *et al.*, 2017a). Naturally, the political influence of this sector has diminished too and it therefore no longer has the influence to secure state funding for predator control. In areas where African people controlled the land over the last century, it seems that predators have been less of a problem. These areas were largely in the eastern half of the country where rainfall is higher and cattle usually the most important element in livestock holdings. African communities were generally more densely settled in these regions and kept predators at bay through herding and regular hunting. As far as African farmers were concerned, the segregationist and apartheid state was little involved in assisting livestock production for the market or for export, although services such as dipping and other veterinary health regimes were provided. Certainly, the state was interventionist, forcing Africans into restricted reserves, homelands, Bantustans and other segregated 'tribal areas' (the vocabulary varied over time). The form of land-holding in these localities was communal, with power of allocation vested in the hands of the chieftain; there was no private property. Moreover, apartheid policy meant that the population in the 'homelands' grew with the forced removal of 'surplus people' into them. Indeed, even agriculture (cultivation) in the 'homelands' was unable to support a sustainable food-producing sector and many parts of South Africa, including the Eastern Cape and parts of the Northern Cape, are unsuitable for crop production (Platzky & Walker, 1985; Dubow, 2014).

Since the 1990s, the national policy has reduced direct support for agricultural activity in historically white areas with land reform and land restitution initiatives, the rise of game ranching, and farm worker activism becoming the norm. On the other hand, the development of the communal areas, neglected by previous governments of South Africa as 'reserves', 'Bantustans' and 'homelands' has become a priority, but predation on livestock in this sector has been little studied.

The current assessment is, in addition, coincident with the growing importance of ethical treatment of non-human animals in South Africa and internationally (Pickover, 2005). Wildlife conservationist sympathies, as well as recent advocacy of animal rights are at odds with some of the traditional values of livestock farmers. Moreover, the scientific environment has also changed with more reliable ecological knowledge available from specialist research in tandem with the growth of the public environmental lobby (Nattrass *et al.*, 2017b). Policies, previously shaped largely by the interests of

white commercial farmers, are now required to mediate conservation and animal rights perspectives, to take account of scientific knowledge, and also to attend to the concerns of rural communities more broadly (Kerley *et al.* 2017). After many years of discussion and consultation, the central government passed the 'National Environmental Management: Biodiversity Act: Norms and standards for the management of damage-causing animals in South Africa' in 2016. The present assessment aims to take the process further.

This chapter outlines the changing scientific paradigms and ecological thinking in terms of attitudes to animals that were once described as 'vermin', emphasising in the main the impact of their predation on stock farming (large and small livestock). It needs also to be appreciated that predator extermination and/or control has an ideological and political, as well as an economic and scientific, rationale. Approaches to predator-livestock conflict have recently also revealed differences between those claiming observational and experiential knowledge (mainly white farmers and hunters) and those claiming scientific authority (nature conservation officials and academic conservation biologists). Nattrass and Conradie (2015) describe these as 'contested ecologies', rivalling one another through different values and politics and by emphasising different aspects of predator ecology. They explain how, in the contemporary Western Cape Province, the debate over how best to control predation became emotional and overtly value-laden, yet potentially open to being shaped by ongoing research (Nattrass *et al.*, 2017a). This, too, is vital background to the issue as people talk past each other from totally divergent paradigms. Conservationists, and to some degree, scientists, have changed their language from discourses about 'vermin' to 'problem animals' and recently to 'damage-causing animals'. At one extreme, writers identify a 'genocide' against a particular species (Van Sittert, 2016). We have not done research on local, farmworker or African knowledge systems in respect of mesopredators and livestock in this chapter and there is little published material.

The black-backed jackal *Canis mesomelas* has been seen as a prime culprit for predation on livestock in the sheep-farming areas over the last couple of centuries. Despite foregrounding this species in this assessment, our knowledge of it is far from extensive. The survey compiled by Nattrass, Conradie, O'Riain & Drouilly (2017b) underscores the level of ignorance about

this species, but also collates published knowledge of an extremely adaptable taxon, provides selected literature, and suggests implications for management. In general, however, the literature on the black-backed jackal and caracal *Caracal caracal* on smaller domestic animals is not only scanty and uneven, but it has also mainly focused on what was formerly the Cape Colony (1814-1910), and Cape Province (1910-1994), and that area itself has been divided into Western, Eastern and Northern Cape Provinces since 1994. The little attention that environmental historians and historians interested in changing agricultural and pastoral practices have paid to the matter has been concentrated in mostly white farming areas in private ownership that are suitable for sheep-farming and thus vulnerable to predation, viz. the Cape region. It is for that reason, together with the fact that it is here that the volume of small livestock is greatest, that attention is devoted mainly to that part of South Africa.

From the perspective of this assessment, it is regrettable that the literature has focused on predation by jackal and caracal on sheep in the Cape region in the commercial farming districts. This is largely because of the rich historical detail that deals with these areas and the centrality of predation in shaping debates about farming practices and conservation. Published data on the situation in the communal areas around the country does not exist in equal measure. In addition, the impact of predation on other agriculturally significant species, such as goats *Capra aegagrus hircus* that are common in communal areas around the country, has also not been determined. For obvious environmental and historical reasons, species like jackal and caracal are numerous in many parts of South Africa and always have been (Skead, 1980, 2007, 2011; Boshoff & Kerley, 2013). Although there are accounts of larger predators like lion *Panthera leo* and leopard *Panthera pardus*, or smaller predators like Cape fox *Canis vulpes*, African wild cat *Felis sylvestris*, and feral dogs *Canis familiaris*, taking livestock in other areas, this happens far more seldom.

The available literature indicates that predator-livestock conflict is more of an issue in the lives of commercial farmers rather than subsistence farmers on communal land, but this may not be an accurate reflection of the real situation in all parts of the country. Nonetheless, the weight on the former may be that commercial sheep farms tend to be extensive, with few

workers, whereas communal farming areas are densely populated (and where dogs are close to small stock). However, communal land near formal protected areas may have problems with predators if labour is unavailable for herding; more research is needed.

PRE-COLONIAL PERIOD TO 1652: GENERAL INTRODUCTION

It is a truism that livestock-keepers from time immemorial have felt the need to protect their flocks and herds from predators to which all vulnerable animals are prey. In Africa, large, or apex, predatory carnivores abounded in bygone eras and over wide areas. Therefore, from the dawn of pastoralism on the continent it has been necessary to provide protection from wild predators for domestic livestock (Smith, 1992). Owing to its particular environmental opportunities and constraints, southern Africa was settled widely by African hunter-gatherers and then by pastoralists in the western parts, and mixed farmers (those who practised pastoralism and planted crops) in the north and east (Mason, 1969; Derricourt, 1977; Inskip, 1979; Peires, 1981; Lewis-Williams, 1983; Pollock & Agnew, 1983; Shillington, 1985; Hamilton, 1995; Laband, 1997; Mitchell, 2002; Huffman, 2007; Swanepoel, Esterhuysen & Bonner, 2008). However, predator-livestock conflict became a matter of governmental concern in the colonial era when an ideology of private land ownership and a market economy, and subsequently a capitalist economic system, were introduced.

Political and economic outline

Precolonial southern Africa had a multi-layered pattern of economies, lifestyles and communities and this is not the place for a full discussion of them. The area of the modern polity of the Republic of South Africa has been inhabited by modern humans for millennia. Archaeologists are currently in agreement that the earliest modern human inhabitants were bands of hunter-gatherers and foragers, generally referred to as San (or Bushmen). It is known that they kept no livestock and cultivated no crops and that their society was based on small, mobile, egalitarian, and generally co-operative, communities or band structures.

Predation on stock/mixed farmers in the interior in the pre-colonial era

Over time, the San foraging and hunting economy was displaced in many regions by intruding societies whose economies and political structures differed markedly. For the purposes of this chapter we identify two of these societies and differentiate between them on the basis of their lifestyles. Broadly interpreted, Bantu-speaking communities can be appreciated for being mixed farmers and skilled iron-makers – and often traders – with sophisticated political hierarchies and economic and social resilience. These traits came into existence owing to the ability to store food (mostly grains) and to husband livestock – almost exclusively cattle but also goats and sheep – and to use the food resources and by-products of those herds. Certainly, it must be surmised that there were many occasions on which humans suffered predation on their livestock from dangerous wild animals.

Evidence from Silver Leaves, Broederstroom, and other sites of the Early Iron Age suggest that these communities settled in fairly large numbers in areas that were good for cattle-raising, where nutritious grassland savanna was available and where livestock diseases were not limiting. The arrival and settlement of cattle keepers and mixed farmers of various communities (e.g. Nguni, Sotho, Tswana – the Late Iron Age) in what are now the provinces of Limpopo, North West, KwaZulu-Natal and the Eastern Cape is well documented (Mason, 1969; Hammond-Tooke, 1974; Maggs, 1976; Maylam, 1986; Huffman, 2007). We have, however, little detail about their relationships with predators of their cattle, but again, it appears from what is known that traditional techniques such as shepherding and night kraaling together with the technical ability to hunt large predators in organised groups may generally have been sufficient to protect their herds from predation (Lye, 1975).

Khoekhoen (Western and Northern Cape)

Unlike the Bantu-speaking mixed farmers, the Khoekhoen (Khoikhoi, sometimes Khoisan) of the south-western and northern parts of what are now the Western Cape and the Northern Cape Provinces can be described as pure pastoralists with fat-tailed sheep as the main form of livestock. They did not cultivate grain or other crops (Smith, 1987). Certainly, it seems that careful shepherding

and stock outposts were the means by which these communities managed their herds. Because of their reliance on livestock as the basis of their lifestyle – their political, religious and economic systems were entirely predicated on the acquisition and ownership of livestock – they lacked the resilience effectively to confront the intrusion of the colonial order. As is well recorded, some groups, the ‘Strandlopers’, who inhabited coastal areas for some or all of the year, relied on marine resources, but the centre of political power more usually resided in the person who owned the largest number of livestock (Elphick, 1985).

Khoekhoen herds were substantial; in 1653, a French sealer recorded ‘thousands of cattle and sheep’ on the plains around St Helena Bay (Smith, 1987:396). Cattle and sheep require different grazing: cattle are less eclectic in their diet than sheep and are bulk grazers and, for this reason, patterns of transhumance (the seasonal movement of livestock) in some parts of the Cape were complex (Smith, 1987: 399). Population records for this era are lacking but certainly the level of human density was low. Records are fragmentary, and information is gleaned mainly from later, often unreliable, accounts left by early European explorers and visitors to southern Africa. What was occurring in parts of the subcontinent in terms of livestock and predator interrelationships in places such as what are now Limpopo Province and KwaZulu-Natal particularly before c.1850 is not known with any certainty, and even the fragmentary oral records are unclear.

It appears that a number of breeds of sheep were kept by the Khoekhoen. In the late 1770s Scottish plant collector William Paterson noted a different variety of sheep in Namaqualand from those nearer Cape Town (Forbes & Rourke, 1980). The ability of the Khoekhoen to combat livestock disease through many natural remedies is well attested (Elphick, 1985). As explained by Elphick (1985), and relying on contemporary sources such as Kolb (1727), at night cattle and sheep were kept within the circular enclosure of the huts or just outside it, with their legs tied so that they could not roam freely. Apparently, lions, and presumably other carnivores and mesopredators, trailed the Khoekhoen bands and were unafraid of attacking the stock enclosures at night (Elphick, 1985). However, it seems relatively clear that Khoekhoen herds were not often allowed to wander without supervision.

Khoekhoen society, grounded as it was on the fragility of livestock ownership (herds could be decimated by disease or drought) and with political leadership the prerogative of those with the largest herds, was extremely vulnerable to the loss of livestock. Despite their fierce resistance, the power of the herders was broken by the combined factors of settler technology, colonial expansion, and the introduction of diseases, particularly smallpox. Their ancestral lands were appropriated by the expansion of white settlers and their stock, and their lifestyle has not survived intact (Elphick, 1985).

COLONIAL/REPUBLICAN PERIOD 1652-1910: THE CAPE, NATAL, TRANSVAAL AND ORANGE FREE STATE

Political and economic outline

The southern part of South Africa was settled in 1652 by a small outpost of employees of the Dutch East India Company (DEIC) as a victualling station for its ships as they plied the route around the Cape of Good Hope to the spice islands of the Far East. At that time there was no intention to establish a colony or even to start a permanent settlement. The Company, based on principles of monopoly, mercantilism, direct profit and minimum investment, envisaged a small station that could provision ships through growing vegetables and other crops that would combat scurvy. They also intended to barter livestock with the Khoekhoen so as to provide fresh meat for ships as they lay in harbour. As is, however, well known, the vision of a contained settlement centred on intensive agriculture and friendly relations with the Khoekhoen soon gave way to an extended area of settler livestock holdings in the interior, fierce opposition from these indigenous people, the introduction of slavery, the establishment of large wheat and wine estates and, in short, a permanent and expanding European foothold in southern Africa that led to hostile relationships with the Bantu-speakers in the eastern parts of the Cape region (Elphick & Giliomee, 1989). By the time that the DEIC collapsed towards the end of the 1700s, local administration and ideas of a contained settlement had broken down completely. The boundaries of the colony were permeable and almost indefensible, and hostilities with the Xhosa on the east were becoming intractable. At the core of this conflict was competition for grazing land

for livestock, particularly cattle which was the economic base of both communities (Peires, 1981).

Moreover, the European context had changed and, with the outbreak of the Napoleonic Wars, and the position of the Netherlands in those conflicts, the Cape became a prize of war. Having been taken by the British in combat in 1795, restored to the Batavian Republican administration between 1802 and 1806, the Cape reverted to Britain in 1806 with permanent occupation confirmed in 1814. With this political change from DEIC control into a formal colonial possession, and the abolition of slavery some years later (1834), one can argue that the modern capitalist era began in South Africa, and with it, formal government structures and 'progressive' pastoralism (Ross, 1986; Beinart, 2003).

As for the interior region, there were, eventually, three settler polities; the Transvaal (the South African Republic, 1852), the Orange Free State (1854), and Natal (1843). Natal was a British colony while the other two were self-governing and fractious Boer republics in which civil war between factions was often rife (Giliomee, 2003). The colonial order arrived in Natal and in the interior around the middle of the nineteenth century together with considerable violence and resistance from African communities. The period from the 1840s to c.1902 saw confrontation between settlers and groups such as the Sotho, Zulu, Tswana and Pedi. Major upheavals included the Mfecane of the 1820s and later wars against the Sotho in the areas that became the Orange Free State and Lesotho, the Zulu in the east, and the Ndebele, Pedi and Tswana in the Transvaal. Dispossession and conquest by the invading settlers occurred on a grand scale, leaving only pockets of land in the possession of its pre-colonial occupiers. Despite strong opposition, eventually the majority became subservient vassals of the whites or migrant labourers on the mines (Keegan, 1986; Beinart, Delius & Trapido, 1986; Davenport & Saunders, 2000). Needless to say, strong government – as was the case in the Cape by this time – did not exist in the interior and thus state support for the settler farming community was absent. In these regions, the very different climatic and ecological conditions in comparison with the Cape militated against successful fleece-bearing sheep at the same scale. Moreover, white settlement, private land ownership and modern agricultural practices arrived later in these places.

Despite British efforts to negotiate some form of confederation from the 1870s, divisions and acrimony

persisted among these political units and the Cape. Further complicating the matter in this period was the discovery of gold and diamonds, and the transformation of, especially, African society and its farming practices to cater for the growing numbers of miners and other immigrants. The mining revolution altered South Africa's history irreversibly. It was not until after the South African War between Britain and the two Afrikaner republics (Orange Free State and South African Republic) in 1902 that effective government was imposed on the region as a whole.

In 1909, a complex and contested Constitution united the four colonies into the Union of South Africa which came into being in 1910. Legacies from the colonial era remained, including some of the powers of the colonies that were transferred onto the provinces. Some of these were by way of dual competencies, e.g. education, health and agriculture, and this dualism has bedevilled the administration of various arms of government to this day.

THE CAPE 1652-1910

The Cape under the Dutch East India Company

Once the DEIC had established an outpost in what is now Cape Town, it began to build up its own herds of livestock, particularly sheep, rather than continuing to barter with the Khoekhoen. Various travellers' accounts record interactions with dangerous large mammals and their predation on domestic stock. Many refer to lion that took horses, sheep and other livestock (Raper & Boucher, 1988). As has been explained, these accounts need to be approached with caution as to their indication of numbers or extent because exciting narratives of lion predation made good stories and sold books (Beinart, 1998). Large predators like lions are a threat to big herbivores like cattle and oxen and it is probable that smaller, adaptable mesopredators like jackal were more of a persistent problem for small stock, including sheep and goats. During the DEIC period protecting livestock generally followed Khoekhoen tradition by way of kraaling and shepherding. According to the settler historian G.M. Theal writing in 1888, the DEIC paid bounties for dead predators, but this was to protect human life and crops as well as livestock (Van Sittert, 2005).

Burchell (1822; 1824) was only one of many contemporary travellers who recorded that the presence of wild animals deterred people from cultivating crops but presumably these were herbivores or grazers, and perhaps also bushpigs *Potamochoerus larvatus* and baboons *Papio ursinus*. He noted also that the Khoekhoen constructed temporary kraals for their sheep when they travelled to fresh pastures, and cattle were tied together to ensure that they did not stray. Noting that lions were around in pursuit of their oxen, Burchell's party lit fires and frightened them away with muskets. Jackals were reported to scavenge on what the lions had left (Burchell, 1822; 1824).

Under the DEIC regime various push and pull factors forced or enticed burghers (freemen) and disaffected company employees to expand beyond the confines of the Cape peninsula. DEIC administration seldom followed them and a culture of self-reliance and independence took hold, together with wariness, indeed abhorrence, of any administration that limited the liberty of a farmer to do as he wished on 'his' land, either privately owned or legally occupied. Intensive agriculture failed outside the confines of the wheat and wine belt around Cape Town and the lure of the interior with its abundant land and opportunity for self-reliance as a livestock farmer was an attraction. Colonists sought to acquire flocks and herds of their own to increase their personal wealth. Burrows has explained how indigenous Cape sheep, providing meat, fat, skins, and currency was a lifeline for the itinerant farmers, referred to as *trekboers* (Burrows, 1952). Colonial expansion in this period was mainly towards the Xhosa-held eastern parts of the Cape where good seasonal grazing was plentiful, but also into the more climatically inhospitable northern Cape. Trekboers were little hampered by organised government and where they met resistance from autochthonous communities they generally took matters into their own hands, thus escalating frontier violence. Access to land for settlers was plentiful by way of the loan farm system, properties for which no fee was required, and that could be occupied or abandoned at the will of the occupier. In addition, herders could be hired relatively cheaply from the impoverished Khoekhoen communities. Trekboers hunted (and even exterminated) wildlife as they travelled, indeed, it was a major form of subsistence (Beinart, 1982; Beinart & Bundy, 1987; Penn, 1987; Van der Merwe, 1995; Penn, 2005).

The colonial experience of the first two hundred years of European rule of the Cape was a process of unrelenting dispossession of land from autochthonous people, a record of livestock raiding and counter-raiding, and endemic violence. It was also the period during which the enormous herds of wildlife and large predators were virtually exterminated from the southern regions of South Africa. By the late 1700s most free-roaming large mammal wildlife had been deliberately extirpated through firearms that had been introduced into southern Africa by Europeans (Skead, 2007; 2011). Even by the 1830s an expedition into the Karoo was needed in order to see any large fauna at all. In this way, the southern part of South Africa was increasingly being made safe for domestic stock held as private property by white settlers. In South African law, domestic stock is private property and can be owned by persons or corporations. However, wildlife is *res nullius*, an object that is unowned. But wild animals can be captured, alive or dead, and a person who captures a wild animal becomes the animal's owner, through a process of acquisition of ownership known as *occupatio*. Such an animal in captivity is the sole property of the captor, or of anyone who subsequently acquires it from the captor. In the 1970s, when wildlife ranching was becoming established and game farmers sought assistance from the Department of Agriculture, a Directorate for Game Farming was set up. As a result of the report of its Committee, although actual 'ownership' of wildlife was not conferred on landowners, a matter for which there was a strong lobby, a concession was made in that if farmers could prove to the authorities that they had fenced in their wildlife satisfactorily, they were eligible for a 'Certificate of Adequate Enclosure' from each of the provinces, a move that entitled them to state subsidies as well as to other benefits (Carruthers, 2008).

What was becoming clear was that sheep-farming by white settlers could prosper in the drier areas of the southern sub-continent (Beinart, 1998) and that by the early 1800s the time was propitious for importing other breeds of sheep into the Cape, particularly wool-bearing varieties. Burrows (1952) records that in 1789 Robert Jacob Gordon, the last DEIC Cape governor, clandestinely imported six Spanish sheep from the Netherlands and that the Van Reenen brothers Jan, Sebastian Valentijn and Dirk Gysbert acquired them and crossed them repeatedly with Cape sheep. This strain was

hardy and less disease-prone than pure-bred Merinos. In 1804, the Batavian regime that had moved away from the DEIC's mercantilist economic policies, having formally proclaimed the colonial boundaries and begun to introduce organised administration, encouraged stock-farming, by way of an investigation under W.S. van Ryneveld. His initial report led to the *Commissie ter verbetering van veeteelt en landbouw* (Commission for the improvement of stock-farming and agriculture) comprising 14 government officials and farmers. Van Ryneveld's recommendations included replacing fat-tailed sheep with Merino, but although Groote Post (near Darling) was established as an experimental farm, the Batavian authorities concentrated on improving agriculture rather than pastoralism. Under British rule the commission's name was changed to the Agricultural Board (Plug, 2004:3-4).

At this time, fewer than 8 000 of the 1.34 million sheep in the Cape were wool-producing Merinos and almost all of them belonged to the Van Reenens (Burrows, 1952). Their form of modernised pastoralism began to spawn a viable rural economy and towns such as Bredasdorp and Caledon were founded on it (Burrows, 1952; Beinart, 1998). This happened despite the fact that many settler sheep-farmers were reluctant to have pure-breed Merino sheep with their lessened resistance to disease (Freund, 1989). In addition, while fat-tailed sheep bunched together when confronted by a threat, Merino scattered, thus making themselves more vulnerable to predators (Beinart, 1998:184).

Freund (1989) explains the change that occurred in the Cape with the formal cession of the colony to Britain in 1814. Thereafter, securely situated in the British Empire, the Cape was catapulted into international trade and benefited economically from the influx of British merchants and the increase in British shipping. As part of an international network of colonial possessions (including those in Australia and New Zealand) the Cape entered the global community. Prior to that time, owing to the unsettled political situation and the frontier wars with the Xhosa, cattle numbers in the colony decreased between 1798 and 1806, perhaps by as much as 25%. But by 1815 numbers burgeoned to more than there had been in 1798. As far as sheep were concerned, already in 1807 there were more than there had been in the 1790s. Colonial sheep numbers peaked in 1811 (Freund, 1989).

The DEIC extensive loan farm system that virtually gave unoccupied land to trekboers was not conducive to large-scale woolled sheep farming because trekboers moved, almost constantly, from one new farm to another. In 1813 the British government introduced the quitrent freehold system that entailed regular rental payments for surveyed farms that had to be productively used and could be sold. This encouraged a more settled white rural community. Eventually, this measure brought a denser pastoral community into being and private land became the norm (Freund, 1989). Between 1814 and 1823 the predator bounty that had existed under the Dutch was revived, but this may not have been related to sheep farming in particular. Van Sittert (1998) asserts that jackals were not included in this bounty system, but this is refuted by Beinart (1998). Moreover, it was not policed. According to Van Sittert (2005), this form of bounty was discontinued in 1828 owing to financial stringency at the Cape.

The situation altered in the 1850s (Nattrass *et al.*, 2017a). There was a wool boom in 1853 and in that year the Cape received Representative Government and thus began partly to manage its own affairs without the requirement to refer every aspect of governance to Britain for approval. The need to nurture wool farmers at this time was extremely important because by 1872 the ever-increasing wool exports had peaked at the huge sum of £3 million (Beinart, 1998). In 1850 in the eastern Cape, Thomas Baines mentioned farmer Currie carefully counting his sheep as they were led into the kraals and he noted that the shearers on Pringle's farm were Africans (Kennedy, 1961; 1964). As Peires (1981) has explained, during this period settler farmers were desperate for labour, particularly after the introduction of woolled sheep, and dispossessed Xhosa, and what were termed 'native foreigners', were permitted to squat on farms as labour-tenants.

Coming from Europe, settlers were familiar with the idea of 'vermin' as a group of predators. In 1889, the Cape parliament (Responsible Government had been granted to the Cape in 1872) instituted a bounty system for specified 'vermin'. This remained in place for more than 50 years. Divisional Councils (the arm of local government in the Cape Colony/Province) were empowered to oversee the process, and hunting clubs were founded and grew in number (Van Sittert, 2005).

Poison was also used; the first Wild Animal Poison Club was established in Jansenville in 1884 and the example was followed in many other districts. Until well into the 1890s there were regular annual congresses of these clubs in the Cape, their activities subsidised by the state (Beinart, 1998; Van Sittert, 1998).

Within a few short decades, woolled sheep were the mainstay of the Cape economy and government protected and supported this industry assiduously. Improved methods of transport, including refrigeration, meant that meat could be transported around the British Empire – mutton was a favourite. Together with increased immigration to South Africa and urbanisation after the 1870s with the mineral revolution in the interior, the sheep farming community of the Cape expanded (Archer, 2000; Cripps, 2012). The mineral revolution wrought even greater changes to African society than it did to settlers. The migrant labour system disrupted communities irreversibly. Some managed to adapt and supply agricultural produce on a basis competitive with white farmers and imports; sometimes as independent farmers, sometimes as sharecroppers (Bundy, 1988). The effect of predation on African-owned livestock in these changing circumstances has yet to be examined.

As was to be expected, once the larger mammals and predators had been extirpated from the Cape, together with the herds of antelope, it was the smaller opportunistic predators, particularly black-backed jackal that had been harassing sheep farmers from the start, that expanded to fill this ecological niche to become the bane of sheep-farmers' lives, affecting their profits. In 1865 one-third of the settler population (58 000) lived in the sheep-farming districts and, as outlined by Archer (2000), technology, notably the industrial production of wire fencing, enabled the industry to burgeon and sheep density to increase. From the 1870s artificial water supplies (drawn from aquifers by windmills) in the drier regions meant that camps within which the sheep ranged freely could be constructed out of imported wire fencing. While the need for kraaling was lessened, the need to protect against predators grew (Archer, 2000). Absolute stock numbers in the Cape grew too: in 1865 there were 10 million sheep and 16.7 million in 1891 (Nattrass *et al.*, 2017a) although numbers fell again during the next 15 years due to war and drought.

The sheep-farming industry had been transformed from nightly kraaling (with its attendant dangers of

disease and veld degradation) with the slow introduction of industrial wire fencing from the 1870s that may have been extensive only by the time of the Second World War. The Fencing Act in the Cape in 1883 (amended in 1891) required farmers to co-operate in the construction and maintenance of fences along common boundaries. Jackal-proof fencing (wire mesh fencing with a packed rock apron) started spreading in the 1890s and fence-making equipment came into play in 1902 (Beinart, 1998). From 1905 subsidies for jackal-proof fencing were paid in the Cape. Cape farmers' cries about 'vermin' and the depredations that they had to suffer on their account were never-ending and owing to the importance of wool exports as a mainstay of the Cape economy, the government continued to listen and to support wool producers. Van Sittert (1998; 2002) cites the fact that fencing tripled between 1891 and 1904 from 4.1 million morgen enclosed to 12.5 million. The situation among African sheep farmers in the communal areas (particularly the eastern Cape) at this time is not known. What is, however, clear, is that dispossessed and displaced Africans and Khoekhoen in the eastern Cape were increasingly being employed as shepherds and herders on white-owned sheep farms at this time.

The bounty system that relied on the production of 'a tail' for reward lent itself to fraud. Consequently, requirements for bounty receipts were constantly tightened. From 1895 vermin tails had to include the bone, in 1896 proof was needed that the tail emanated from the Cape Colony, in 1899 a bounty payment required tail, scalp and ears and the signature of a Justice of the Peace or landowner, and in 1903 the whole jackal skin had to be produced. Select Committees looked at the matter. One report was published in 1899, *Report of the Select Committee on the Destruction of Vermin*, but the outbreak of the South African (Anglo-Boer) War prevented further action until a second Select Committee sat in 1904 (*Report of the Select Committee on the Destruction of Vermin*). Predator control was clearly high on the government agenda (Beinart, 1998).

The bounty expenditure was considerable. In 1898-1899 bounties on jackal tails (7 shillings each) amounted to the not inconsiderable sum of £28 000 and thus represented more than 50,000 jackal that were killed (Beinart, 1998). But in 1908, mainly because of fraud, vermin bounties were abolished in the Cape.

The post-war depression of 1904 to 1907 affected all four colonies as the export price for wool collapsed and evidence of veld degradation became ever more apparent (Beinart, 1998). Van Sittert (1998) argued that the bounty system was helpful not only in controlling vermin but also in alleviating poor white poverty. It may also have created cohesion among whites of all classes and the establishment of farmers' associations assisted this process further. How many black people were paid out for proofs is not a matter that is formally recorded for this period. Beinart (1998; 2003), however, notes that African areas were relatively free of jackal because communal areas could be controlled by groups of people, not individual owners, and there was consequently no consideration of private property or issues of trespass. In addition, the large numbers of dogs kept by Africans were destructive to smaller predators like jackal and caracal and it may even have been that black farmworkers and independent hunters killed predators for the bounty.

No 'scientific ecological research', as currently understood, was conducted on predators like jackal and caracal by museums or university colleges. Natural history societies proliferated in the late nineteenth century but the ethos of the time was on teaching the type of zoology that was current in Europe (if it was taught at all), on the collection of specimens, and on close taxonomic study. The place of predators in any kind of what would now be called an 'ecological system' was limited to a few voices that need to be understood in the context of their time and the emphasis on introducing a modern agricultural economy. One of them was F.W. Fitzsimons, Director of the Port Elizabeth Museum from 1906 (Beinart, 1998). The demands of politically powerful Dutch- and English-speaking farmers (Tamarkin, 1995) for the persecution of predators like jackals held sway.

As indicated, the main characteristic of this pre-Union period in the Cape was the dispossession of local communities from ancestral lands and their replacement by a private property regime, settler farming practices and a market economy. The Khoekhoen herders were unable to sustain themselves as a cohesive society once they had lost their cattle, and despite numerous wars, in time, the Xhosa of the eastern Cape were pushed eastwards. Certainly, they continued to husband livestock and grow crops, but they had access to ever-decreasing areas of land. How this influenced the predation of their livestock

has not been examined. However, African cultural practices such as loan cattle (*mafiso*, where shepherds cared for the livestock of a chief or headman in exchange for some of the progeny of the herd), may have increased the number of herders and shepherds. For example, the large herds of a chief were not protected by him alone, as was the case with settler farmers. Practices such as loan cattle, the use of the youth etc. meant that labour for shepherding and herding was generally always available.

Natal, Transvaal (South African Republic 1852-1902) and Orange Free State (1854-1902, Orange River Colony 1902-1910)

Natal was annexed by Britain in 1843 primarily to prevent permanent settlement by the Voortrekker groups who had vacated the Cape in the 1830s during the 'Great Trek'. This was not sheep-farming country. Hot summers and high rainfall were detrimental to woolled sheep and a special type that might have acclimatised was not bred. The presence of predators was a far lesser threat than worms and other sheep ailments and diseases. Sheep could not range freely in the veld (as they could in the Cape) but had to be confined in camps. Unlike in the Karoo, there was a shortage of mineral salts in the soils of Natal, and careful veld burning was required. In the seasonally very hot Natal, flocks had to trek onto the cooler Highveld in summer (Anon., 1929). Zululand, nominally independent until 1897 when it was annexed by Natal, is also not suitable for sheep-rearing but has always been well known for cattle-keeping, the main economic resource of the Zulu (Guy, 1982).

In comparison with the Cape with its longer history of white settlement, large game remained plentiful in Natal until well into the 1800s. Predator control among the Zulu in the pre-colonial and colonial periods is not well studied but it is likely that cattle were protected from lion and other predators as a matter of course. Struthers, in 1854, relates how 'tigers' (probably leopards) in a tree near the wagons attacked six dogs, only one of which returned three days later with 'fearful holes in its neck and shoulder' (in Merrett & Butcher, 1991:49). At a similar time, Delegorgue explained how Zulu cattle were penned every night into a kraal with a circular hedge, fairly close to the huts and all surrounded by an external fence for protection against attack from 'hyaenas and

panthers who are so bold that they enter huts and seize the dogs sleeping at the owner's feet' (Delegorgue, 1997). In the 1890s Tyler recorded lions in the Zulu cattle folds (Tyler, 1971).

Of jackal and other predators and livestock (particularly small stock) in the growing agricultural economy in the greater area of KwaZulu-Natal before Union in 1910, the historical record is mostly silent. It seems likely that predation on small livestock as hampering productive livestock farming has historically been an issue in the Cape rather than evenly country-wide although we cannot be sure.

As the Cape became more densely settled and with the enclosure (fencing of farms) movement gaining pace, intrepid missionaries, explorers and land-hungry settlers – and the Voortrekkers for different reasons – ventured into the interior. Initially, Britain claimed these territories, but during a period of financial stringency, it granted independence to the Transvaal in 1852 (the South African Republic or ZAR) and to the Orange Free State in 1854 by the Sand River and Bloemfontein Conventions, respectively. Many travellers and explorers between the 1830s and 1860s commented on the large herds of wildlife and the abundance of predators. The hunting literature is extensive, and this genre spawned an appreciation of the 'excitement' of the interior regions as well as providing a record of the decimation of elephant *Loxodonta africana* and other large wildlife (Gray, 1979). Not for many years was settled agriculture and property ownership consolidated in the Transvaal and Orange Free State. Moreover, this was generally cattle country, although Sandeman, travelling in the Free State in 1878 on his way to Pretoria, described wool as the staple article of the republic (Sandeman, 1975). It is not clear how many sheep there were, nor the herding practices or mesopredator losses. In 1850 Baines, then on the Marico River among the Tswana in what is now the North West Province, described how a lion had been among the cattle and badly injured them (Kennedy, 1964). Selous, one of the most famous of the sport-hunters, recorded that predators, when encountered, had to be driven off by specifically employed African herders otherwise they would attack donkeys and horses (Selous, 1999). Apparently, in 1833 near Clocolan (now in the Free State) a group of missionaries heard jackal and 'tigers' one night and the following morning one of their

sheep was missing (Boshoff & Kerley, 2013). There is not sufficient anecdotal evidence such as this to reliably inform a coherent account of the situation before the twentieth century in the interior of what was to become South Africa (but see Keegan, 1986).

After the South African War had ended in 1902 and the two republics had become British colonies – the Transvaal Colony and the Orange River Colony – the government established Departments of Agriculture on the same basis as was the case in the Cape and Natal. Progressive agricultural expert Frank B. Smith became head of the Department in the Transvaal and Charles M. Johnston (a keen and knowledgeable ornithologist) in the Orange River Colony. An early edition of the *Transvaal Agricultural Journal* (1904) posted a notice on the 'Destruction of Vermin' instituting bounties for targeted animals among which jackal were included. Leopards (often referred to as 'tigers' following the Dutch and Afrikaans terminology), then still existing in the more remote localities were worth 10 shillings, wild dog *Lycaon pictus* 7 shillings and 6 pence, silver and red jackal (the side-striped *Canis adustus* and black-backed jackal – not 'maanhaar' jackal, viz. insectivorous aardwolf *Proteles cristatus*) 5 shillings, and caracal, 5 shillings. In order to obtain the reward, the tail and the skin of neck and head of the destroyed animal had to be presented to the Resident Magistrate together with a written declaration that the creature was killed within the boundary of the colony. If the animal was young, the whole skin had to be shown. If required, poison (strychnine) was made available from the Resident Magistrate at cost price. It is clear that this notice followed very closely the situation in the Cape at that time (Anon., 1904). No analysis of the records of Resident Magistrates has been done to ascertain how many rewards were paid, to whom, or when. The few records in the National Archives of South Africa accessed using the keywords 'vermin' and 'ongedierte' (for the Transvaal database accessed via NAAIRS – the National Automated Archival Information System) provides only minimal information about the destruction of stock by domestic dogs.

The guiding philosophy of settler farming in the post-war colonies, particularly in the Transvaal under Smith, was to recover from the destruction of the countryside that had occurred over the three years of hostilities and

to restock farms, introduce new grasses and crops and formalise agricultural policy. The colony also needed to attract English-speaking settler farmers. To these ends, Smith employed qualified staff such as Joseph Burt Davy, Illtyd Pole Evans and Charles Legat, and he retained veterinarian Arnold Theiler (later Sir Arnold) who had been employed by the Transvaal republican government. In 1902 he initiated the *Transvaal Agricultural Journal*, published in both English and Dutch. Smith's difficulties in guiding these processes and dealing with placating the vanquished and still hostile Boer population were immense.

One of the problems at this time regarding sheep farming in the wetter parts of the interior was endemic livestock disease, of which southern Africa has many and that have been augmented by some Australian sheep diseases. The challenges in dealing with them were extremely difficult and only with time, and the invention of appropriate pharmaceuticals and strategies, have some of them been overcome. The ecological role of jackal in disease transmission has not been fully elucidated, nor has the effect of the rinderpest epizootic of the 1890s on sheep been adequately explored (Jansen, 1977; Bingham & Purchase, 2002).

AFTER UNION IN 1910-1990

Political and economic outline

Because, traditionally, the issuing of hunting licences, determining closed seasons, and advertising 'royal' game and 'vermin' species was a responsibility of the four colonies and was regarded as merely an administrative function, 'Game and fish preservation' remained in the hands of the provinces under the Union constitution by Section 85 of the South Africa Act 1909, 85(x). Game reserves were then few in number and southern Africa could boast only one national park, in Natal, founded in 1906 (Carruthers, 2013). Game and fish preservation and game reserves were administered within the general ambit of provincial management.

This changed as a consequence of the Financial Relations Consolidation and Amendment Act 38 of 1945 that obliged the provinces to reformulate their nature conservation and other structures. Responses to this obligation in the Transvaal, Orange Free State and the Cape resulted in 'nature conservation' (the terminology

had changed from 'game and fish preservation') departments or divisions being formed within the existing provincial government structures in the late 1940s and finally in the Cape in 1952. In Natal a semi-independent parastatal with the title of the Natal Parks, Game and Fish Preservation Board was established in 1947. Somewhat ironically in the light of later environmental thinking and the stricter interpretation of 'nature conservation' in South Africa, the introduction and management of trout *Oncorhynchus mykiss* and brown trout *Salmo trutta* continued to be the responsibility of these authorities as did vermin control. Moreover, it was only after the post-war environmental revolution of the 1960s that the biological sciences began to respond to conservation matters, including ideas around 'threatened' or 'endangered' species, (Carruthers, 2011).

However, one needs to bear in mind that much of the legislation was directed for the benefit of white people, not Africans. Indeed, the Natives Land Act 27 of 1913 restricted the amount of land at their disposal. Many segregationist and apartheid laws impacted negatively on African farmers. 'Betterment' philosophies enabled the state to interfere directly in African farming. Livestock herds were limited and, at best, subsistence, but not sustainable, agriculture and pastoralism continued to limp on. Africans expelled from white-owned property added to the numbers evicted from those forbidden by law to seek livelihoods in the city (Platzky & Walker, 1985; Davenport & Saunders, 2000). Whether black-backed jackal and other mesopredators survived in these generally desolate, overcrowded homelands to prey on African-owned cattle, goats and sheep is not a matter of record.

From the outset of Union, vermin destruction was in a somewhat anomalous position in government. Certainly, hunting permits came from game and fish preservation authorities, but a strong interest in the matter came from the national Department of Agriculture, the arm of government tasked with promoting effective and profitable farming. As defending the private property of farmers, and with agriculture and pastoralism being in the national interest, the Department had a duty to support farmers and to assist in protecting their property. Moreover, the farming, or rural, vote was critically important to politics. Until 1990 all four provinces had programmes to manage predation by black-backed

jackal, but from the 1980s there were concerns in this regard. Animal rights, financial stringency, and the growth of wildlife ranching – together with greater ecological understanding – initiated new thinking about predator control (Bergman *et al.*, 2013). These factors have been responsible in later years for raising the profile of livestock predation in the Cape and the involvement of national government.

The Cape Province 1910-1990

In the Cape, the neglect and disruption of the country during the South African War had allowed jackal numbers to rise. Apparently, Sir Frederic de Waal, Administrator of the Cape from 1911 to 1925, took on the 'jackal question' with enthusiasm. His energy in counteracting the activities of the 'free-booting jackal' was as much, it seems, an exercise in creating harmony between the Dutch and English farmers as it was to nurture the sheep farmers at a time when the price of wool and mutton were rising (Beinart, 1998). The number of woolled sheep in the Cape Province rose from 13.3 million in 1918 to 18.6 million in 1927, peaking at 23.5 million in 1930 before being affected by the fall in wool prices in the Depression (Beinart, 1998:204).

Owing to the fact that the outbreaks of scab meant that kraaling was discouraged, more Cape sheep roamed in large paddocks than before. This may well have made them easier prey. The jackal bounty was raised, hunting and poisoning this species on state land was prioritised, while hunting hound packs were subsidised and poison supplied to white farmers, but not to Africans (Beinart, 2003). The bounty system was revived in 1913 and remained operative until 1957. In 1917 the Cape's foundational Vermin Control Ordinance established 17 effective 'Circle Committees' in the 85 Divisional Councils (a form of local government specific to the Cape) that relied on local government structures for their effectiveness in compelling the establishment and maintenance of hunting clubs, ignoring trespass traditions and otherwise penalising farmers who did not control jackal effectively. At almost regular intervals the Vermin Control legislation was updated, with a major alteration in 1946 that even classified dassies *Procavia capensis* (rock hyrax) as vermin. Over the years, the definition of 'vermin' was widened to include animals that damaged fences or were otherwise detrimental to

sheep farmers. Thus, together with fencing and windmill and other government subsidised technology between 1914 and 1923, allied to state assistance with eradicating predators (including the use of poison from 1929), the tide turned on the jackal and numbers began to decrease, although their disappearance was geographically uneven (Beinart, 1998; Natrass & Conradie, 2015; Van Sittert, 2016; Natrass *et al.*, 2017a).

A significant change in philosophy and management took place after the institution of the Nature Conservation Department in 1952 and with Douglas Hey, a trout scientist, in charge of it. Given Hey's familiarity with new environmental thinking, the discourse altered from old-fashioned 'vermin' to 'problem animals' and 'extermination' gave way to 'control'. Hey explained how extermination was neither desirable nor practicable and that predators should be regarded as useful animals integral to South Africa's natural heritage (Hey, 1964).

Hey began to dismantle the bounty system in the early 1950s and ended it finally in 1957 (14 species had been on the list in 1956). The province turned towards 'technical aid' to farmers to control problem animals, i.e. improved subsidies to hunt clubs, better training, and an improved breed of hounds. Near McGregor, at Vrolijkheid (currently a nature reserve), a Hound Breeding and Research Station was established in 1962 where hunting packs were trained. In 1966 another training depot began in Adelaide, where environmental and climatic conditions were different. According to Stadler (2006), Adelaide 'gradually developed into a fully independent functional unit and the centre of all Problem Animal Control activities for the Eastern Cape'. Moreover, to serve the northern Cape where hunting with hounds was not possible, training courses on the use of traps began and, in 1973, a third Problem Animal Control Station was established at Hartswater. This facility focused on the provision of advice and training – no hunting hounds were maintained. There was great demand for the hunting hounds from these stations, but farmers also benefited from training courses that included ethical nature conservation, trapping and the translocation of problem animals (Stadler, 2006).

By the mid-1960s, the jackal was still the major predator of sheep, but was regarded as 'relatively well controlled' through hunting, trapping and poisoning (Hey, 1967). By contrast, the caracal was increasing

in range and in some places becoming the dominant predator of sheep, small antelope and game birds, prompting Hey to comment that there would thus 'seem to be some ecological relationship between these two animals'. Hey also commented on the rise of baboons as a predator of sheep, linking this to declining leopard populations (Hey, 1967).

Hunting club data from the Ceres Karoo and the Eastern Cape revealed that most livestock loss at the end of the 1970s was caused by caracal. Analysis of these data indicated that killing stray dogs reduced stock depredation the following year, whereas culling caracals and leopards increased future losses – suggesting that hunting these predators made the problem worse for farmers, presumably through compensatory breeding and immigration (Conradie & Piesse, 2013).

Predation on sheep continued to have a high profile in the Cape, resulting in a further 'Commission of investigation on vermin and problem animal control in the Cape' being appointed in 1978. There were 30 recommendations, including the reduction of the list of 'declared vermin' to just three (caracal / lynx, black-backed jackal and vagrant dogs). However, the remaining recommendations were implemented only in 1984 and, according to Stadler (2006), the most important of these was the replacement of an older vocabulary including 'extermination, exterminate, destruction, destroy, vermin' with that of 'control, problem animal, combat and combating'. Hey retired in 1979 and nearly a decade later, in 1987, his Problem Animal Control Section was dismantled and its functions relegated to other sections. This was part of a wider process of deregulation and the withdrawal of government assistance in agriculture in the 1980s. In 1988 the subsidy of hunt clubs ended, in 1989 the facilities at Vrolijkheid and Adelaide were given over to the private sector (*viz.* the farmers themselves) for research and management, and free training courses ended in the mid-1990s (Stadler, 2006; Van Sittert, 2016).

The Transvaal, Natal and Orange Free State 1910-1990

As has been explained, predation by meso-carnivores on livestock was far more important in the Cape region than elsewhere. It was, however, a central theme in the woolled sheep-farming districts of South Africa (including in the Orange Free State) and farmers there had for many decades called on the state for assistance in combating predators, particularly, but not exclusively jackal. In the 1930s, for example, a farming journal reiterated that most of the Transvaal bushveld region was 'livestock country' in which Merino could not survive, although there was an experimental station at Pietersburg (now Polokwane) working on a cross-breeding project to develop an appropriate mutton sheep variety (Anon, 1930).

Nonetheless, the other three provinces all had various iterations of predator legislation in the years after Union. In 1983, for example, there was the Natal Ordinance 14 of 1978, the Orange Free State Ordinance 11 of 1967, and Section c.II of the Transvaal Nature Conservation Ordinance 11 of 1967. Moreover, the Administrators of these provinces had the power to declare any species of wild animal to be a 'problem animal' in the whole or part of the province (Fuggle & Rabie, 1983).

An agricultural census of the Transvaal in 1918 showed that there were 637,000 head of sheep producing some 4.5 million kg of wool, mostly in Ermelo, Wakkerstroom and Standerton on the temperate highveld. The census of 1993 recorded 458 000 head of cattle and 598 000 sheep that yielded nearly 7.8 million kg of wool. However, it was also noted that after 1950 the number of farms had declined from 10,000 to 5,400 (Schirmer, 2007). The matter of predation was not highlighted in the census. Although Africans had restricted access to land and markets – and worked within a hostile political environment – some made entrepreneurial economic contributions either within the 'homelands' (if they had access to land there) and also as tenants on white-owned farms. Nonetheless, the comment has been made for Mpumalanga (at that time part of the province of Transvaal) that by the late 1980s African agriculture (cultivation) had all but ceased but probably livestock keeping had not. With 60% of Africans living in the reserves it is unlikely that free-ranging mesopredators were a substantial problem (Schirmer, 2007:311). In socio-economic terms,

paternalism and dependency were created by apartheid and the legacy of this era endures.

There are no detailed historical accounts of vermin extermination or control in these three provinces thus flagging the fact that it had, for many reasons, a lower profile in these areas. Beinart (1998) mentions that the first detailed studies of jackal diets took place in the Transvaal between 1965 and 1971. Some 400 jackal stomachs were analysed. Of those killed in game reserves 6% had sheep remains in their stomachs, of those in farming districts, 27% (Beinart, 1998). Determining whether the jackal had actually killed the sheep or merely fed on the carcasses of already dead animals is not possible.

Even if numbers were low, farmers were not deterred from addressing the matter, presumably taking their lead from the Cape. Perhaps the most famous hunting club in recent years has been Oranjejag that operated with government subsidies, and notoriety, from 1966 to 1993 in the sheep-farming districts of the Orange Free State and western Transvaal (Faure, 2010). The existence of Oranjejag was mandated by the Free State Problem Animal Control Ordinance and between 1966 and 1993 it killed some 87,570 animals in the Orange Free State alone but, alarmingly, some 70% (60,340) were Cape (silver) foxes *Vulpes chama* that take insects and other small prey (Daly *et al.*, 2006). In the western Transvaal a problem animal station for hounds and farm training was set up at Panfontein, near Bloemhof, in what is now the North West Province and the S.A. Lombard Nature Reserve.

1990 TO PRESENT

In the early 1990s, a loose consultative structure known as the National Problem Animal Policy Committee (NPAPC) appears to have been fairly successful at drawing together government officials from nature conservation authorities, the old regional services councils, hunters and industry organisations such as the Red Meat Producer's Organisation (RPO) and the National Wool Growers Association (NWGA). At a conference in the Orange Free State in 1993, delegates reportedly emphasised the need for ongoing government support for predator control given the imminent demise of Oranjejag, the last remaining hunt-club, due to the cessation of state funding. This process, however, reportedly 'faded' as it was overtaken by political events, notably the creation of

nine new provinces (with new administrations) as South Africa transitioned to democracy in 1994 (De Waal, 2009).

Generating new institutions and legislation (especially regarding land reform and security of tenure of farm workers) dominated the agricultural agenda for the rest of the decade. Matters of interest to stock farmers were divided between the new departments of Agriculture, and Environmental Affairs and Tourism. Managing 'damage-causing animals' was left to the provinces, although over time their scope was restricted by national legislation. In 1995 the NPAPC recommended that in updating and creating appropriate legislation, the provinces refrain from assigning problem animal status to any species, that animals causing damage be dealt with through translocation and regulated hunting, that problem animal hunters be required to undergo some training (e.g. attend an accredited course). In addition, it was suggested that landowners should not be compelled to join hunt clubs, and that hunt clubs not be allowed to access private property without permission (Stadler, 2006). In the Western Cape, Cape Nature Conservation (subsequently known as CapeNature) started a process in 1996 to revise the legislation (notably Ordinance No. 26 of 1957 as amended) around the control of damage-causing animals. This involved consultation with animal rights groups, environmental organisations, farmers and academics. This lengthy process was shaped also by changing national legislation, notably the National Environmental Management Biodiversity Act (Act 10 of 2004) which *inter alia* further restricted the use of poison and hunting with dog packs. Additional regulations (in terms of the 1947 Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act 36 of 1947) were passed in 1996 and 2003 outlawing the use of pesticides and other remedies to poison predators (Predation Management Forum, 2016).

The use of poison was curtailed in the 1970s by the Hazardous Substances Act 15 of 1973. From then onwards, sodium monofluoroacetate (also known as 1080) was restricted for use on toxic collars only (and the sellers of such collars had to be licenced) and other hazardous substances like strychnine were regulated (and subsequently outlawed). Cyanide was limited for use in the coyote getter (and producers had to be licenced to sell them). Farmers wanting to use such methods also had to comply with provincial legislation and regulations

from local conservation bodies. The Firearms Control Act 60 of 2000 outlawed previous models of coyote getters (the ones with firearm ammunition) but allowing newer models that projected poison capsules. In 2005, CapeNature obtained legal opinion on its emerging draft regulations and decided to end the provision of training in the use of the coyote-getter with immediate effect (given its potential to kill many non-target species) and started investigating further restrictions on the use of gin traps (as these are increasingly regarded as cruel and non-specific). In 2007, CapeNature formed a partnership with an environmental non-governmental organisation to work towards the elimination of gin traps and to promote 'holistic' non-lethal predator control methods. Then, in late 2008, CapeNature announced that from January 2009, various control methods, including night-hunting of jackals, would no longer be allowed. By this stage, however, small stock farmers and their organisations were complaining vociferously about what they were experiencing as a sharp increase in predation (especially by black-backed jackals) from the mid-1990s, and a bitter contestation emerged (Nattrass & Conradie, 2015). The Western Cape government subsequently backed down in the face of industry pressure, making it easier for farmers to obtain permits to shoot jackals and caracals provided that data detailing mortalities were provided.

The issue also played out at on the national stage as the NPAPC engaged with the then Department of Environmental Affairs and Tourism (DEAT), resulting in a meeting in January 2009, that, in the eyes of one observer, 'may have caused more discord than synergy' (De Waal, 2009). DEAT then released draft 'Norms and Standards for the Management of Damage Causing Animals', which the agricultural industry regarded as 'biased', demanding that both agricultural and environmental departments be involved (De Waal, 2009). It also prompted the National Wool Growers Association and the RPO to join with the South African Mohair Growers Association and Wildlife Ranching South Africa to form the Predation Management Forum (PMF) in 2009. This organisation remains a powerful lobby for the industry, providing advice online and over the phone, and most recently, producing a booklet on how to identify predators and what methods can be used to control them. The booklet provides an overview of key national legislation, but given the complexity of the relevant provincial legislation and

related ordinances, simply directs farmers to their local government offices to 'familiarise themselves' with the precise legal context they face with regard to managing predators on their land. At the end of 2016, the legal environment for managing damage-causing animals remained bewilderingly fragmented.

On 10 November 2016, the minister of Environmental Affairs finally published the 'Norms and Standards for the Management of Damage-Causing Animals in South Africa' (RSA, 2016). It begins by stating that everyone has a 'general duty of care to take reasonable measures to prevent or minimise damage caused by damage-causing animals (4.1), and this sets the tone for a set of guidelines that present lethal control as a strategy of last resort. The legal framework for methods regularly used by farmers (cage traps, foothold traps, call and shoot, poison collar, hounds, poison firing apparatus and denning) remain unclear, with guidelines stating that these methods 'may require a permit, issued by the issuing authority, in terms of any applicable legislation' (8.1). It also includes specific 'minimum requirements' for the use of traps, collars etc. Those engaging in 'call and shoot' activities have to be adequately trained, 'comply with the conditions applicable to the use of the call and shoot method, as determined by the relevant issuing authority', submit records of call and shoot events and 'must target only specific individual animals known to cause damage' (12 (1)). The latter requirement is onerous (and thus likely to be ignored) given that it is impossible to know which individual predator is causing damage.

CONCLUSIONS

The above outline of the history of the management of predation on livestock has highlighted how uneven and complex this matter has been and remains. This is so, whether the issue is considered ecologically (in terms of various parts of South Africa), or in terms of impact on different farmers and communities (regionally, racially, and economically); philosophically (in terms of societal attitudes towards predators/vermin), and politically (meshing national and provincial structures over the long history of the subcontinent). A reality emerging is that whatever methods applied in attempts to curb or halt the onslaught on mainly small stock by jackal and caracal over the past 350 years of colonialism, these have proved ineffective over the longer term, although

there were periods in which management in whatever form was more successful than others in certain regions. Moreover, in a global context of volatile wool and meat prices, and an ever-changing national context in which agriculture has a declining share of GDP and urbanisation is burgeoning, the future policy environment is bound also to be difficult and complex. In addition, as explained by Nattrass *et al.* (2017b), and that will emerge from the chapters that follow, formal scientific knowledge of mesopredators is far from extensive and many of these species are elusive and highly adaptable. Policy-making at a national level under these circumstances is bound to be difficult. The issue at the heart of this assessment is whether the state has an obligation to protect livestock farmers in South Africa from certain species of predators. Protecting livestock from errant individual large fauna, such as elephant or lion that may escape from protected areas, is very different from providing regulations for a specific section of the population that farms with sheep.

Box 2.1 Important knowledge gaps

From a historical perspective and at a high level, the following knowledge gaps can be identified:

- » Predator control in the precolonial era (Khoekhoen, Early and Late Iron Age)
- » Detailed historical evidence relating to livestock predation and its management in provinces other than the Cape Colony/Cape Province/Western Cape/Eastern Cape.
- » Historical information in respect of predator control in African communal areas in 19th and 20th centuries.

TIMELINE

- » c. 2 000 BP Evidence of livestock keeping in southern Africa.
- » 1652 Arrival of the DEIC (Dutch East India Company) at the Cape.
- » 1656 DEIC pays rewards to kill lion, 'wolves' and leopard.
- » 1783 DEIC rewards for killing elephant, rhinoceros, giraffe, eland, lion and zebra.
- » 1795 Cape taken over by Britain. DEIC bankrupt, Battle of Muizenberg.
- » 1802 Cape returned to the Netherlands under Peace of Amiens. Ruled by the Batavian Republic that had nationalised the DEIC.
- » 1806 Cape reverts to rule by Britain after renewed Napoleonic Wars. Battle of Blaauwberg.
- » 1814 Cape formally ceded to Britain by the Netherlands and comes under the formal permanent control of Britain by Convention of London. Vermin bounty introduced.
- » 1828 Vermin bounty discontinued.
- » 1843 Natal annexed as a British Colony.
- » 1852 Transvaal gains independence from Britain as the Zuid-Afrikaanse Republiek.
- » 1853 Cape Colony receives Representative Government.
- » 1854 Orange Free State gains independence from Britain as a republic.
- » 1865 Approximately one-third of the settler population (58 000) lived in the sheep districts. 13 million stock of all kinds.
- » 1870s Introduction of cheaper wire fencing.
- » 1872 Peak of wool exports at over £3 million.
- » 1872 Cape Colony receives Responsible Government.
- » 1883 Fencing Act finally passed in the Cape Colony (amended 1891)
- » 1884 First Wild Animal Poison Club established in Jansenville. Many followed in subsequent years. Subsidy offered for vermin tails.
- » 1886 Cape Game Act 36. Jackal exempted from hunting restrictions.
- » 1887-1890s Annual congresses of Wild Animal Poisoning Clubs
- » 1890s Vermin-proof fencing introduced.
- » 1895 Cape bounty restricted to vermin tails with bones.
- » 1896 Cape bounty payment required proof that the skin came from the Cape Colony.
- » 1896 Rinderpest epizootic
- » 1899 Cape bounty payment required tail, plus scalp and ears and signature of Justice of the Peace or landowner.
- » 1899 Select Committee instituted in the Cape Colony to investigate the reward system.
- » 1899-1902 South African (Anglo-Boer) War.
- » 1902 Fence-making machines introduced.

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- » 1903 Cape bounty payment required whole skin.
- » 1904 11 million woolled sheep in the Cape Colony. 30 000 jackal killed for reward.
- » 1904 Select Committee instituted in the Cape Colony to investigate the reward system.
- » 1904 Vermin bounty regulations published in the Transvaal Agricultural Journal, vol. 3
- » c. 1904-1907 Economic depression in southern Africa. Collapsing export wool price and veld degradation.
- » 1905 Assistance from the Cape Colonial government for vermin-proof boundary fencing included in Fencing Act.
- » 1908 Vermin bounties abolished in the Cape Colony mainly on account of fraud.
- » 1910 The Cape, Orange River, Natal and Transvaal colonies amalgamate to form the Union of South Africa. 'Game protection' established as a provincial competency.
- » 1911 Division of Sheep established in the national Department of Agriculture.
- » 1911-1925 Cape Administrator Sir Frederic De Waal took active personal interest in the 'jackal problem' and prioritised sheep farming over other forms of agriculture.
- » 1912 Fencing Act 17. State subsidy available for fencing.
- » 1913 2 8 million woolled sheep in the Cape Colony. Wool exports second only to gold.
- » 1913 Cape Province revives bounty system.
- » 1914-1918 First World War.
- » 1917 Cape Vermin Control Ordinance established 17 'Circles' based on electoral districts (not Divisional Councils) under committees. Bounties subsidised by the Province.
- » 1917-1921 Annual Vermin Extermination Congress held under the 1917 Cape Ordinance.
- » 1918 First agricultural census
- » 1918-1927 Number of woolled sheep in the Cape Province between 13.3 million and 18.6 million.
- » 1920s Shepherding plus kraaling on commercial farms generally replaced by artificial water provision and fenced camps.
- » 1923-1924 Vermin Extermination Commission
- » 1923 Cape Vermin Extermination Ordinance revised.
- » 1923 Drought Investigation Commission.
- » 1929 Poisoning of vermin allowed in Cape Province.
- » 1930s Economic depression in southern Africa. Fall in wool prices.
- » 1930 Peak of woolled sheep numbers in the Cape Province at 23.5 million.
- » 1939-1945 Second World War.
- » 1946 Cape Vermin Extermination Ordinance revised and extended. Wide powers.
- » 1940s-1952 Establishment of nature conservation authorities in all 4 provinces.
- » 1950s-1960s Shifting environmental philosophy towards understanding ecological systems.
- » 1951 Cape Province phases out bounties to replace them with 'technical aid'.
- » 1955 Administration of vermin removed from the General Section of the Cape Provincial Administration to the newly formed Department of Nature Conservation.
- » 1955 Douglas Hey's Commission of Enquiry, report published in 1956. 'Predator control' rather than 'vermin extermination'.
- » 1957 Cape provincial bounty system ended.
- » 1957 Cape Province Problem Animal Control Ordinance 26.
- » 1950s Favourable wool, pelt and meat prices encourage continued sheep farming in the Cape.
- » 1954 Hound-breeding station established at Panfontein. S.A. Lombard Game Reserve, near Bloemhof.
- » 1958 Hound-breeding station established, Vrolijkheid, at Robertson.
- » 1961 South Africa becomes a Republic.
- » 1961 Introduction of poison 1080 (sodium fluoroacetate), disallowed after 1973 with Hazardous

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- Substances Act.
- » 1965-6 Hound-breeding station established at Adelaide.
 - » 1966 Oranjejag established.
 - » 1967 Transvaal Province Problem Animal Ordinance 11
 - » 1967 Orange Free State Province Problem Animal Ordinance 11
 - » 1972 Hound breeding station begun at Hartswater to serve the Northern Cape.
 - » 1973 Hazardous Substances Act limits the use of certain poisons, including those previously used on carnivore predators.
 - » 1978 Second Commission of investigation on vermin and problem animal control in the Cape. List of vermin restricted to caracal/lynx, black-backed jackal and vagrant domestic dogs.
 - » 1978 Natal Province Problem Animal Ordinance 14
 - » 1979 Orange Free State 'Verslag van die Kommissie van Ondersoek na Ongediertebestrijding en Rondloperhonde in die Oranje-Vrystaat'.
 - » 1980 81 registered and subsidised vermin-hunt clubs in the Cape. Hey unable to abolish them owing to political pressure.
 - » 1987 Problem Animal Control Section abolished in the Cape and distribution of poison, coyote-getters and baits discontinued.
 - » 1988 Subsidies to Problem Animal Management Hunt Clubs discontinued.
 - » 1989 Discontinuation of hound breeding and training in the Cape.
 - » 1990s Inter-provincial Problem Animal Control Committee established. Prior to 1990 all four provinces had programmes to manage black-backed jackal.
 - » 1992 Peter Kingwill, Chairman of the National Problem Animal Policy Committee called for a national policy and strategy for problem animal control.
 - » 1994 Oranjejag officially disbanded.
 - » 1994 Constitutional change in South Africa to a fully democratic republic. Four provinces converted into nine.
 - » 1995 Recommendations to the provinces from the Inter-Provincial Problem Animal Control Committee.
 - » 1996 Officials of CapeNature conclude that problem animal legislation outdated. Draft regulations for the Cape completed in 2002.
 - » 2009 Widely representative task team to formulate Norms and Standards for management of damage-causing animals established. Formation of Predation Management Forum.
 - » 2010 Publication of 'Draft Norms and Standards for Management of Damage-Causing Animals in South Africa' in *Government Gazette* 33806, Notice 1084, 26 November 2010.
 - » 2016 Publication of 'Norms and Standards for Management of Damage-Causing Animals in South Africa' in *Government Gazette* 40412, Notice 749, 10 November 2016.

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THE SOCIO-ECONOMIC IMPACTS OF LIVESTOCK PREDATION AND ITS PREVENTION IN SOUTH AFRICA

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INTRODUCTION

Livestock predation occurs in nearly all rangelands around the world, and usually leads to some level of investment in predator control in order to minimise economic losses. These measures are often controversial due to uncertainty about their effectiveness and concerns about their impacts on animal welfare, biodiversity, ecosystem functioning and populations of endangered species.

THE management of predators on private rangelands in South Africa has changed dramatically over time. Changes in management practices have been driven by changes in technology as well as changes in scientific understanding and public sentiment. Boreholes and large-scale fencing were introduced in the late 1800s, which enabled commercial livestock farmers to change from a kraal system to one where sheep were kept in camps. Government introduced programmes to facilitate jackal-proof fencing and the extermination of predators from camps (Nattrass *et al.*, 2017). Predator removal was achieved through a bounty-hunting system that persisted until the 1950s, and then by district hunting clubs that employed professional hunters, supplied hunting dog packs and trained farmers in trapping and poisoning. These state-supported measures led to high rates of killing of a number of species including non-predatory species that competed for grazing such as rock hyrax ("dassies") *Procavia capensis*. With this support, farmers were able to employ 'fence and clean-up' methods to great effect (Nattrass & Conradie, 2015; Nattrass *et al.*, 2017). Problems were reportedly greatly reduced between the 1920s and the 1960s, but

caracals *Caracal caracal* and later black-backed jackals *Canis mesomelas* started to increase again thereafter. Government support of the commercial agricultural sector started to diminish in the late 1980s and along with it, public assistance for the control of predators. This added to the increasing difficulties in making a living from livestock farming in the face of decreasing product prices, decreasing government subsidies and increasing input costs.

It is likely that other factors have also contributed to the reported increase in predation problems in recent years (Nattrass & Conradie, 2015). In particular, free-roaming wildlife populations in rangeland areas, which would form the natural prey of the problem animals, have been diminishing over time (Ogutu & Owen-Smith, 2003; Owen-Smith & Mills, 2006), probably at least partly as an indirect result of predator management activities. In addition, new legislation and the opening up of South Africa to international tourism also encouraged the proliferation of game farming from the early 1990s (Taylor *et al.*, 2016), which may have further reduced the numbers of free roaming game as these populations were fenced. More recently, increasing awareness and

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concern about animal welfare, endangered species and effectiveness of certain methods has led to greater restrictions on the focal species for control, as well as the methods of control, which means that the way in which farmers can deal with problem animals has become more restricted.

Therefore, by all accounts, today's farmers are faced with a very different situation than at any previous time. The current situation for commercial farmers has been fairly well documented in a series of recent studies of small-stock, large-stock and game farmers throughout South Africa (van Niekerk, 2010; Thorn *et al.*, 2012; 2013; Badenhorst, 2014). Small-scale and subsistence farmers in communal lands had not enjoyed government support in the past, and there is relatively little information on the effect of predation and on farmer responses in these areas (e.g. Gusset *et al.*, 2008; Chaminuka *et al.*, 2012; Sikhweni & Hassan, 2013; Hawkins & Muller, 2017), though much more is known from comparable areas in other parts of the continent.

It is now up to both commercial and subsistence farmers to take their own decisions as to how much to invest in predator control. As a rational '*Homo economicus*', a farmer's decision would be based on an assumed relationship between the level of investment in anti-predator measures, the value of the losses avoided and their budget constraint. Their implicit decision model would be based on past experience and reports of predation rates in the area and understanding or beliefs of the effectiveness and costs of different measures. However, in reality, farmer decisions are also likely to be driven by cultural traditions and beliefs, lifestyle choices, ethical stance, risk profile and tendency for compliance, as well as consideration of neighbour behaviour. These decisions may also be expected to differ between private and communal lands. Unlike private farmers whose decisions take place in the relatively closed-system context of fenced land, communal farmers are not likely to be able to control predation risk without strong co-operation within their communities. Therefore, communal-land farmer decisions in this regard would be likely to be driven primarily by the need to protect stock rather than eliminate predators. This recalls the strong sentiment among commercial farmers that being able to move from herding and kraaling as a result of fencing, water and other advancements has been an important determinant of commercial success. Communal farmers do not have the same choices.

While private and communal farmers act in their own

interest, the hypothetical social planner that guides policy will also take the costs and benefits to other members of society, including future generations, into account. If a farmer's actions impose external costs on the rest of society, such as loss of endangered species, these will need to be internalised. In a nutshell, livestock losses should be weighed against the value of biodiversity losses. Since it is difficult to obtain satisfactory estimates of the latter, policy relies on well-informed value judgements to some extent. Unless ways are found to identify and achieve the optimal level of co-existence, farmers may suffer excessive losses, ecosystems may be out of balance with cascading consequences, and conservation managers may fail to achieve the levels of biodiversity protection that society desires. What is clear is that scientists and policy makers in these two spheres of interest will need to work together to better understand the impacts of predation and the effectiveness of different measures in reducing these risks. This understanding is crucial in order to determine an optimal path for society and the policy measures required to get there.

This chapter draws on the international literature to achieve a broad understanding of the economic and social aspects of predator-livestock issues, and summarises current understanding of the situation in South Africa. We review information from commercial livestock and wildlife-based enterprises on private lands, as well as small-scale and subsistence farming areas of communal lands. We then focus on synthesising current understanding on the costs incurred to farmers in preventing and succumbing to livestock depredation, and the broader economic and social implications of this. The attitudes and investment decisions of farmers are also discussed. The impacts on biodiversity and overall policy implications are discussed in subsequent chapters.

OVERVIEW OF THE LIVESTOCK AND WILDLIFE FARMING SECTORS

With very little land area being arable and 91% of the land being classified as arid or semi-arid, the majority of South Africa's land area (69%) is under rangeland (WWF, undated; DAFF, 2016). Livestock farming is therefore the largest agricultural sector and contributes substantially to food security. Livestock accounts for 47% of South Africa's agricultural GDP and employs some 245 000 workers (Meissner *et al.*, 2013).

Livestock carrying capacity increases from west to east with increasing rainfall (Figure 3.1). Sheep are the main livestock in the drier western and central areas, while cattle tend to dominate in the wetter eastern rangelands. However, many rangeland areas are stocked beyond their long-term carrying capacity, particularly in the communal rangelands of Limpopo, KwaZulu-Natal and the Eastern

in the drier regions of the country. These include mutton sheep, particularly the Dorper, which is adapted to harsh conditions, and wool sheep, mainly Merinos. Overall numbers of sheep have decreased to 68% of their numbers in 1980 (DAFF, 2016), and the proportion of Merinos has also declined, from 65% to 52% of total sheep numbers. Goat numbers have diminished to 72%

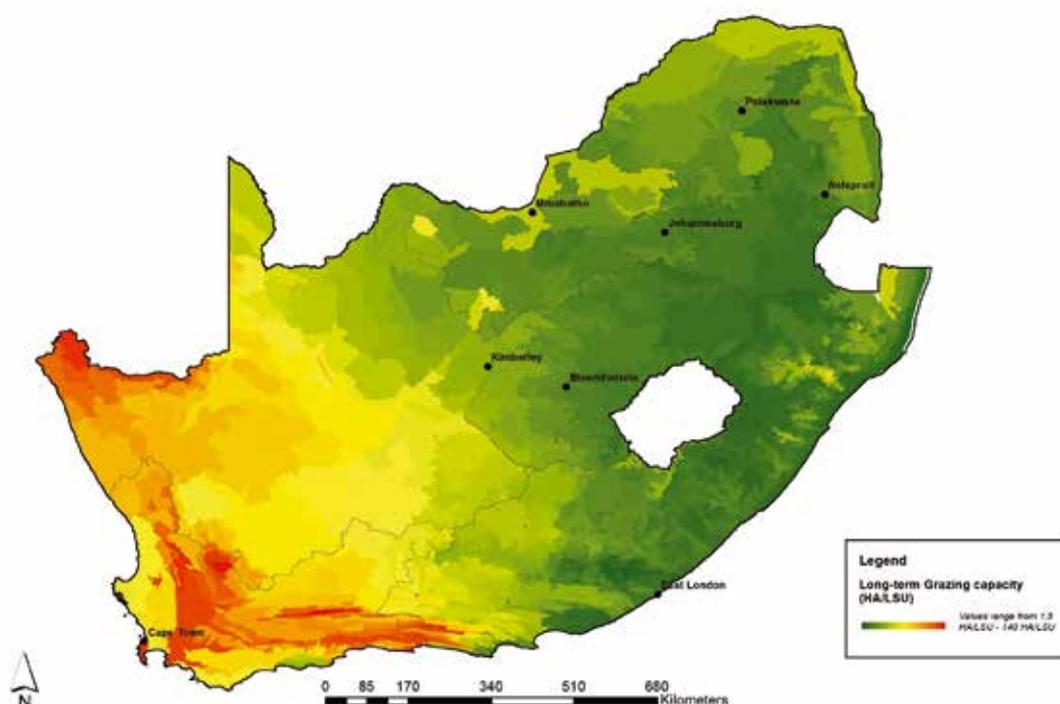


Figure 3.1. Livestock long-term grazing capacity (ha/LSU). Source: DAFF (2017).

Cape. These small scale/communal farming areas support more than half of South Africa's cattle (DAFF, 2017) and are important for rural livelihoods, but they contribute comparatively little to marketed production. Game farming has mainly proliferated in the more mesic eastern and northern areas, but is also common in the arid areas.

As of 2010, South Africa had an estimated 13.6 million beef cattle, 1.4 million dairy cattle, 24.6 million sheep, 7 million goats, 3 million farmed game animals, 1.1 million pigs and 1.6 million ostriches in addition to poultry (Meissner *et al.*, 2013; see Figure 3.2). These are raised on about 38,500 commercial farms and by some two million small-scale/communal farmers (Meissner *et al.*, 2013).

Sheep and goats are farmed extensively, particularly

of their numbers in 1980. Commercially-farmed goats are dominated by Angoras and Boer goats, with indigenous goats being farmed in the emerging/communal sector. Ostriches are also important in some areas.

Declines in sheep numbers are a worldwide trend (Morris, 2009), and relate to decreasing prices of products such as wool, as well as increased input prices, reduced subsidies and labour market reforms. However, it is important to note that small ruminants are relatively resilient to higher temperatures, and their importance may increase again under future climate change conditions (Rust & Rust, 2013). Globally, the sheep farming industry has undergone major efforts to improve productivity and profitability, for example through adaptive management. In New Zealand reproductive efficiency improved from a lambing percentage of less than 100% in the late

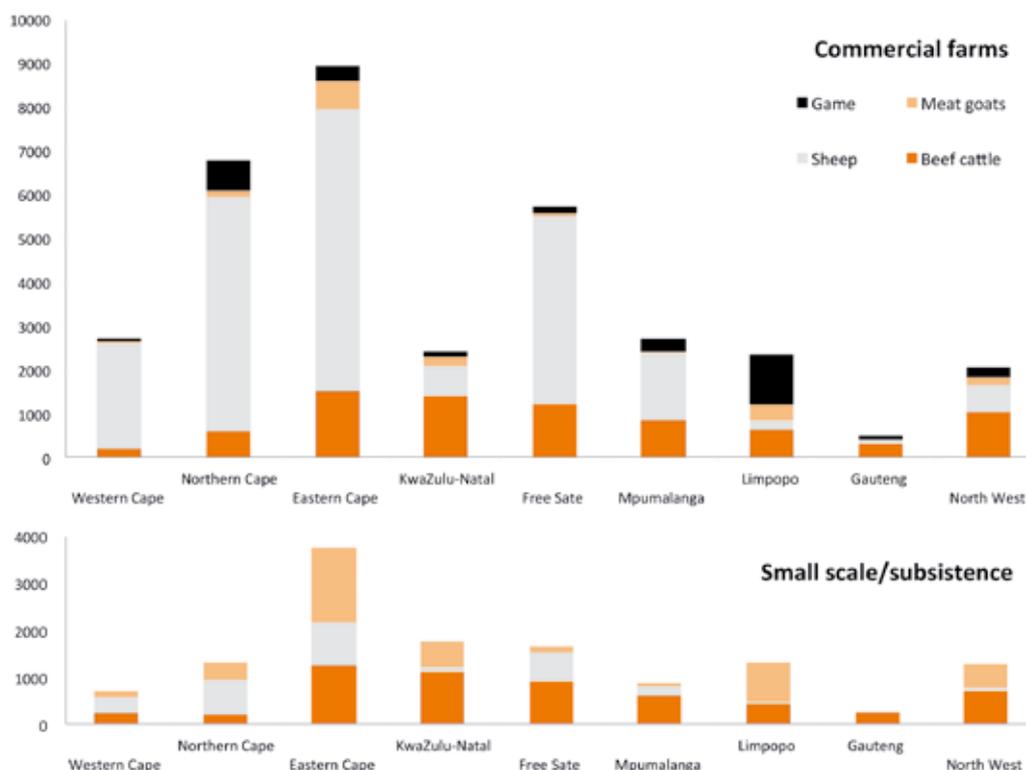


Figure 3.2. Estimated cattle, sheep, goat and game numbers in South Africa (2010) (in thousands). This excludes 21 000 dairy goats and 1 million Angora goats. Source: Meissner *et al.* (2013).

1980s to 125% by 2008 (Morris, 2009). However, there was little technical progress in South Africa's sheep farming districts during 1952 to 2002 (Conradie *et al.*, 2009) while in the rest of agriculture there was technical progress of 1-1.5% per year over a similar period (Thirtle *et al.*, 1993). Furthermore, past attempts to accelerate technical progress in sheep farming areas (Archer, 2000) might have led to over exploitation of rangeland (Dean *et al.*, 1995; Archer, 2004; Conradie *et al.*, 2013). Thus the small stock sector is particularly vulnerable and is in urgent need of innovation in the areas of genetics and breeding, nutrition and research on pasture management, strategies to improve reproductive efficiency and deal with labour constraints. Strategies to improve prices such as the Karoo Lamb certification initiative are also very important.

In contrast to small stock, the national cattle herd increased since the 1970s along with increasing domestic demand for beef (Palmer & Ainslie, 2006), but has remained fairly stable since 1980 (DAFF, 2016). These cattle are not entirely supported by rangelands, as

75% of South Africa's cattle spend a third of their lives in feedlots (WWF, undated).

Whereas wildlife ranching was still fairly rare in the 1960s, the industry started growing in the 1970s and 1980s (Van der Waal & Dekker, 2000; Smith & Wilson, 2002; Carruthers, 2008; Taylor *et al.*, 2016), and then increased exponentially in response to the increasing demand for wildlife-based and trophy-hunting tourism following South Africa's transition to democracy, as well as increasing problems of stock theft. This development was facilitated by the promulgation of the Game Theft Act of 1991, which made provision for rights over wildlife held in adequately enclosed areas. Wildlife farming is now common in most provinces, replacing both small- and large-stock farming, but the extent of the activity has not been quantified.

Over these same time periods, the numbers of farmers and farm workers have decreased markedly. Largely as a result of farm consolidation, there has been a 31% decline in the number of farmers since 1993, and the number of farms (including crop farms) has decreased

by 40,000 (WWF, undated). Small and marginal farmers that had been reliant on subsidies and soft funding from institutions such as the Land Bank started to suffer as support was withdrawn, markets opened up and competition increased. These farms were bought out, farms were consolidated and farming net incomes grew considerably as a result of economies of scale (WWF, undated). The decrease in agricultural labour is likely to have resulted from both the consolidation of farms and the development of stricter labour laws (Turpie, 2003). These changes are particularly relevant in the broader socio-economic context in which South Africa finds itself in the 21st century. Declines in income and employment in the livestock sectors and associated declines in the economies of small towns have probably contributed to the high levels of poverty and inequality in the country. The challenges faced in these areas also have an important bearing on land reform and the establishment of emerging black farmers.

THE NATURE OF LIVESTOCK DEPREDATION

Livestock predation in South Africa is predominantly by the black-backed jackal *Canis mesomelas* and caracal *Caracal caracal*, which are common throughout the country. In the main small-stock farming areas, these species account for over 65% and 30%, respectively, of predation losses overall (Van Niekerk, 2010). Large predators such as lions *Panthera leo*, African wild dogs *Lycaon pictus*, and spotted hyaena *Crocuta crocuta* occasionally occur on private lands in the northern and eastern parts of the country, but are only resident inside protected areas and private reserves with predator-proof fencing (Thorn *et al.*, 2013). Other mammal species that take livestock include leopard *Panthera pardus*, cheetah *Acinonyx jubatus*, brown hyaena *Hyaena brunnea*, dogs *Canis familiaris* and baboons *Papio ursinus*. Leopards, cheetahs and brown hyaenas are commonly found outside protected areas (Mills & Hofer, 1998; Marnewick *et al.*, 2007) and are threatened by persecution in farmlands (Friedmann & Daly, 2004). Outside protected areas, leopards now tend to be largely confined to mountainous terrain (Norton, 1986; Skinner & Smithers, 1990). Baboons occur throughout, but do not commonly kill livestock (van Niekerk, 2010; Thorn *et al.*, 2012; 2013).

Domestic dogs can be a significant problem, however, particularly near towns (Davies, 1999; Thorn *et al.*, 2013). Black-backed jackal and caracal account for most predation on small stock throughout the main farming provinces (Figure 3.3. van Niekerk, 2010, see following page). Jackal are also the main predator of cattle throughout all cattle provinces apart from Limpopo (Figure 3.3; Badenhorst, 2014). While caracal are also the second most important predator of cattle, a number of other predators play an important role, notably leopard, which was the most important predator in Limpopo province, and brown hyaena. Studies of unselected farm types in Limpopo and North West which both had a high proportion of game farmers showed that jackal, caracal and leopard were the main predators, with leopard being the most important in North West (Figure 3.3; Thorn *et al.*, 2012; 2013).

It is interesting to note that eagles were not mentioned in any of these studies. The larger eagle species such as martial eagle *Polemaetus bellicosus*, Verreaux's eagle *Aquila verreauxii* (also known as black eagles) and crowned eagles *Stephanoaetus coronatus* are quite capable of killing small livestock, and can take sheep up to half of adult size. Because of this, large numbers of Verreaux's and martial eagles were hunted in the Karoo in the 1960s (Siegfried, 1963). Livestock do not form a major part of their diets, however. Studies of prey remains in the Karoo have shown that sheep comprise less than 2% of Verreaux's eagle diets, and that a Verreaux's eagle pair consumed about three lambs per year on Karoo farmland (Davies, 1999). These predation events were too rare to be picked up in observations. However, in denser vegetation of the Eastern Cape, lambs have been found to comprise 8% of prey remains of Verreaux's eagles (Boshoff *et al.*, 1991). Farmers give highly variable accounts of losses to eagles: Davies (1999) reported that half of 37 farmers interviewed reported no lamb losses to eagles, 27% reported occasional losses and 24% reported significant losses. It is likely that whereas most eagles do not actively hunt livestock, a few pairs may take to doing so. The cost of having eagles on a farm is probably negligible (Davies, 1999). Based on necroscopy studies, Davies (1999) found that eagles were responsible for only 1% of kills in South Africa, whereas their role was far more significant in other countries, especially the UK (16% of kills).

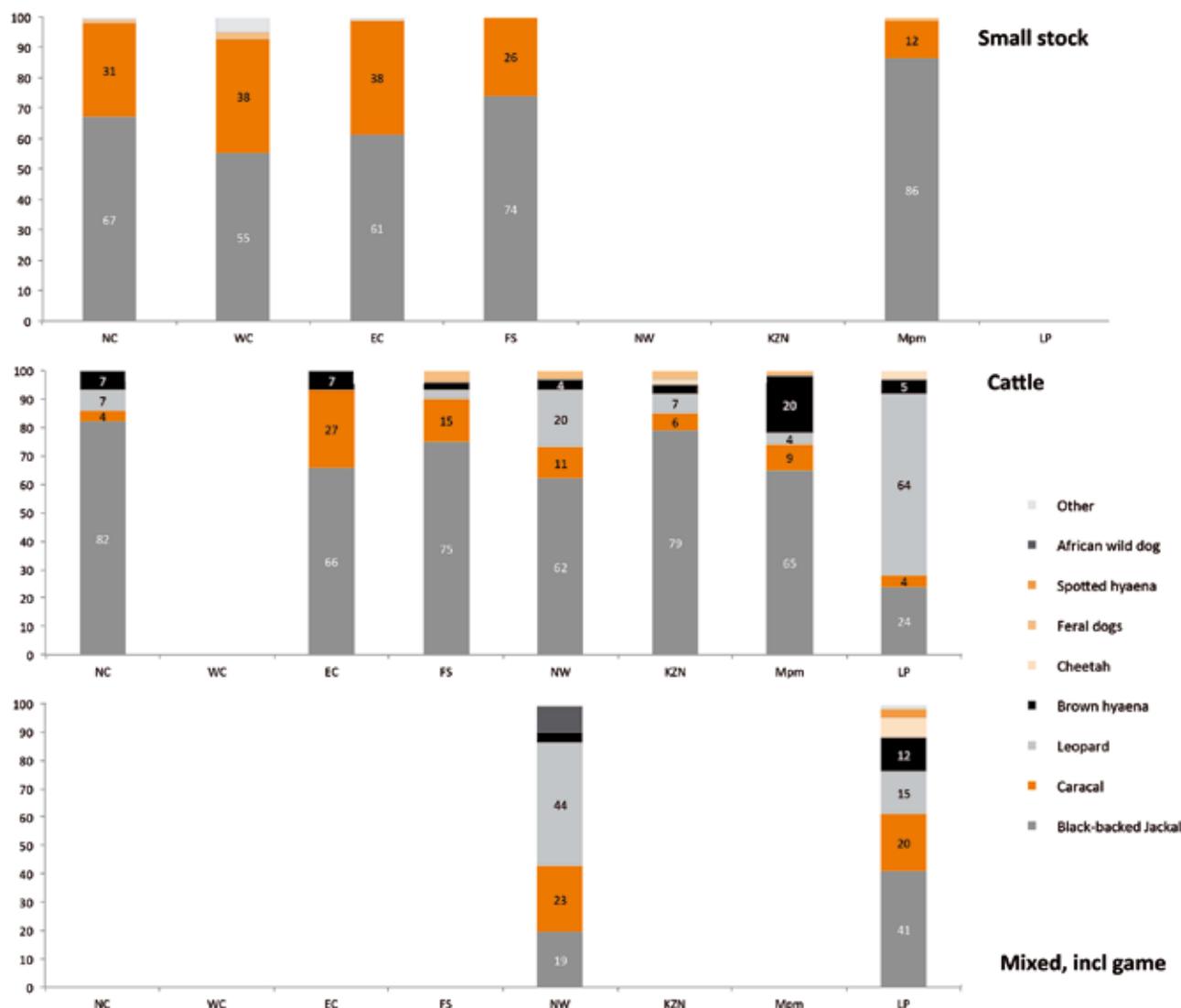


Figure 3.3. Relative extent of predation on commercial farms by different predator species in the provinces in which farmers were surveyed. Sources: Small stock farms – van Niekerk (2010); cattle farms – Badenhorst (2014); all types of farms - Thorn et al. (2012, 2013).

With most of the predators being relatively small, it is generally reported that livestock depredation is almost entirely of very young animals. In a study of small-stock farmers across the country, van Niekerk (2010) found that the majority of losses were of animals less than one month old. De Waal (2009) also reported predation on sheep farms to be mainly of young lambs before weaning, and Viljoen (2016) reports that 89% of all predation mortalities of wool sheep occur before weaning age. In the North West, 57% of farmers (all types) claimed that most of the game and livestock animals preyed upon were <12 months old, with game animals preyed

being species with adult female body weight between 23 and 70 kg (Thorn et al., 2013). Goats and sheep were the most affected livestock and cattle were less affected (Thorn et al., 2013). It is important to note that predation losses can be reported in various ways, e.g. relative to the numbers of lambs born, breeding ewes or total stock or for limited age categories (e.g. lambs only). In this assessment, we have attempted to collate data on total losses as a proportion of total stocks as far as possible, but deviations from this are made clear where appropriate.

THE EXTENT OF LIVESTOCK DEPREDATION

Private rangelands

While livestock depredation has always been a concern for farmers in South Africa (Beinart, 1998), there have been very few quantitative estimates of the problem until relatively recently. Early studies have been criticised as being overestimates. In some cases, this was thought to be due to exaggeration of the problem by farmers (Nesse *et al.*, 1976; Armentrout, 1980; Boshoff, 1980; Hewson, 1981 in Davies, 1999), or their tendency to ascribe unknown causes of losses to predation. In other cases, this is due to sampling bias. For example, Brand (1993) calculated that losses from black-backed jackal ranged from 3.9% to 18%, but these estimates were probably biased towards high predation areas and farmers that encountered losses (van Niekerk, 2010). In a 19-month study of 8 farms, Rowe-Rowe (1975) estimated that jackals resulted in annual losses of only 0.05% of the total sheep population in KwaZulu-Natal.

It can be difficult to assess the quality of farmer responses in studies of predator losses. Not all losses are actually observed, as some animals simply go missing. Some lambs may be scavenged after death, and usually only parts of carcasses are found, so that cause of death is uncertain (Strauss, 2009). Also, determining the type of predator responsible may not always be easy, and kills by less common predators might be wrongly assigned. Farmers may also bias their responses for strategic reasons. A more reliable way to determine the causes of livestock deaths is through necropsy studies undertaken by independent observers. Based on data

from a number of such studies collated from sheep farms around the world, Davies (1999) found that predators were responsible for a much lower proportion of losses than is typically reported (Table 3.1). The estimated predation loss for South Africa (1%) was much lower than previous and subsequent survey-based estimates, but was based on a relatively small sample size of 191 carcasses (Davies, 1999). Note, however, that this estimate is from a time when predator control was far more co-ordinated and intense. A more recent estimate obtained from monitoring farms set up by the wool industry suggests that 46% of all lamb mortalities are due to predation (Viljoen, 2016).

However, the reliability of estimates of studies such as Viljoen (2016) and those cited in Davies (1999) is questionable. Studies vary greatly not only in terms of who collects the data, the extent to which farmers actually visit the kill sites and who judges the accuracy of predator identification, but also in their sample sizes and representativeness. Some of the earliest datasets come from the hunting clubs that were established to control predators in the past. Hunting club data provide information on kills in Karoo farming areas during the 1970s and 1980s, such as the Cooper Hunt Club in the Mossel Bay area for 1976-1981, and the Ceres South Hunting Club data for 1979-1987 analysed by Bailey & Conradie (2013) and Conradie & Piesse (2013). However, these datasets do not include numbers of livestock on the monitored farms, so could not be used to estimate predation rates as a percentage of stock. Systematically-collected data have only started to emerge in recent years.

Table 3.1. A geographical summary of results on neonatal lamb mortality derived from field necropsy surveys. Losses are expressed as % of lambs born. Source: Davies (1999).

Country	No. carcasses	% lambs lost to predators	% lambs lost to other causes
South Africa	191	0.9	16.15
United Kingdom	1 423	0.32	35.5
Australia	15 704	1.66	16.81
New Zealand	?	?	16
United States	12 660	6.42	6.42

Growing concerns about livestock depredation in South Africa led to estimates of the scale of the problem. For example, Bekker (2001, cited in Stannard, 2005) estimated that 1 million sheep were being lost annually, and the National Wool Growers Association (NWGA) estimated a loss of 8% (2.8 million head of small stock, 2007) of stock per year (De Waal, 2009, in van Niekerk, 2010). These concerns have recently led to a series of studies to quantify the problem more accurately, all based on interviews with commercial farmers. Van Niekerk (2010) telephonically interviewed 1,424 farmers in the five major small livestock producing provinces – the Western Cape (published in van Niekerk *et al.*, 2013), Northern Cape, Free State, Mpumalanga and Eastern Cape. Another smaller study was conducted on 58 farmers in the Laingsberg area in 2012 by Conradie & Landman (2013). Badenhorst (2014) reported on a study of 1,344 cattle farmers in seven provinces. Another study involved telephonic interviews with 99 farmers in North West Province (Thorn *et al.*, 2012) and the managers of 95 farms in Limpopo province (Thorn *et al.*, 2013). Schepers (2016) undertook a survey of 201 wildlife ranchers (all members of the Wildlife Ranchers of South Africa – WRSA) in Limpopo Province. Other studies are ongoing, including a large multi-year study in the Western Cape, and another study of a set of monitoring farms set up by the wool industry.

Van Niekerk (2010) and van Niekerk *et al.* (2013) estimated that predators were responsible for the losses of 6.2% to 13% of sheep and goats in the five provinces

of their study (Table 3.2). These estimates are consistent with data obtained by Conradie & Landman (2013) for the Laingsberg area of the Karoo, which suggested that 9% of stock were lost to predation (12% were lost to all causes). Interestingly, the predation percentage for mutton sheep was greater than for wool sheep (6% on smaller farms, $n=8$, to 19% on larger farms, $n=12$) compared with 7% ($n=12$). This is possibly because wool sheep tend to be more actively managed (Conradie & Landman, 2013). Lawson (1989) reported a lower predation rate of 3% for sheep farming in KwaZulu-Natal.

In a study of Angora goats on stud farms, Snyman (2010) could only name a probable cause of death in 30% of deaths of pre-weaned Angora goat kids which had an average mortality rate of 11.5%. Of these, predators accounted for 39%. While this was more than any other cause, the mortality from predators (4.5%) was low relative to the rates reported for general small stock (Table 3.2).

Thorn *et al.* (2012; 2013) estimated losses of about 1.4-2.8% of total game and domestic livestock holdings in Limpopo and North West Provinces (Table 3.2). The Limpopo and North West studies included all types of farms, which were dominated by game farms. Since cattle and game present far fewer opportunities for predation than do small stock due to their size alone, one would expect lower rates of predation in their studies. Indeed, cattle farms reported by far the lowest losses, with losses in all cases being less than 1% of their herds (Table 3.2; Badenhorst, 2014).

Table 3.2. Estimates of predation losses as a percentage of stocks based on interview data. Sources: Lawson (1989), van Niekerk (2010), Thorn *et al.* (2012, 2013), Badenhorst (2014).

Province	Predation losses as a % of all stock		
	Small stock	Large stock	All types, including game
Western Cape	6.2		
Northern Cape	13.0	0.11	
Eastern Cape	11.8	0.06	
KwaZulu-Natal	3.0	0.50	
Free State	7.6	0.25	
Mpumalanga	8.0	0.25	
Limpopo		0.86	1.4
North West		0.51	2.8

The overall losses reported for mixed farms in the savanna biome are very much in line with the rates of loss reported from elsewhere. For example, based on a global review, Meissner (2013) reports that domestic livestock depredation leads to annual losses of 0.2-2.6%. Many studies from the region are also in this range. For example, losses of 1.4%, 2.2%, 1.8% and 4.5% of stock holdings have been reported in Namibia, Botswana, Kenya and Tanzania, respectively (Marker, Mills & Macdonald, 2003; Kolowski & Holekamp, 2006; Holmerna, Nyahongo & Røskaft, 2007; Schiess-Meier *et al.*, 2007). However, it is clear that the type of farming is a very important factor. The above findings suggest that stock losses on South African commercial cattle farms are relatively small, whereas those on commercial small stock farms are high (Table 3.2). If there is any accuracy to the perception that these predation rates are rising, then small-stock farmers in particular may be facing significant difficulties.

Communal rangelands

Livestock kept in unfenced communal grazing areas are also vulnerable to predators. This is evidenced from the numerous studies that have taken place in communal rangeland areas of eastern and southern Africa (Rasmussen, 1999, Butler, 2000, Patterson *et al.*, 2004, Woodroffe, Lindsey, Romanach, Stein & Ranah, 2005; Kolowski & Holekamp, 2006; Holmerna *et al.*, 2007; Lagendijk & Gusset, 2008; Chaminuka *et al.*, 2012; Sikhweni & Hassan, 2013). Again, several authors caution that the extent of damage caused may be exaggerated, because local people affected by livestock losses fail to take into consideration other threats to livestock including disease, accidents and theft (Holmerna *et al.*, 2007; Kissui, 2008; Dar, Minhas, Zaman & Linkie, 2009; Dickman, 2009; Atickem, Williams, Bekele & Thirgood, 2010; Harihar, Ghosh-Harihar & MacMillan, 2014). Thus studies that account for all these causes are likely to be more reliable. It is also important to note that because livestock ownership tends to be skewed, with a few people owning a large proportion of the overall herd, the estimates of overall, average and individual losses may differ substantially.

Many of the studies on communal rangelands have been concerned with predation levels in the areas surrounding protected areas. For example, Butler (2000)

found that predators killed 5% of livestock (dominated by goats and cattle) in the Gokwe communal land area adjacent to Sengwa Wildlife Research Area (in Zimbabwe), with losses amounting to 12% of income among livestock-owning households. Most of these losses were due to baboons (52%), lions (34%) and leopards (12%), and almost all predation was on goats and sheep. Similarly, losses due to livestock depredation were estimated to amount to 25% of the per capita income of farmers in Nepal (Oli *et al.*, 1994). In Tanzania, stock loss to carnivores was reported by Western Serengeti villagers as two thirds of the average annual income (Borge, 2003). Around the Makgadikgadi Pans National Park in Botswana, where cattle are let out of their kraals in the morning and left unattended all day, overall losses to predators amounted to 2.2% and average losses were 5.5% (Hemson *et al.*, 2009). This was mainly due to stray cattle taken at night by lions. Farmers also suffered overall losses of 3% to disease and 1% to theft. In Kenya, Patterson *et al.* (2004) estimated the predation of livestock to represent 2.6% of the herd's value.

Communal farmers in South Africa also farm under widely variable conditions, ranging from arid Karoo veld to the more mesic areas of the north east of the country. Relatively few studies have been carried out in South African communal lands. These have focused on the arid communal rangelands of the Northern Cape, the areas surrounding the Kruger and Hluhluwe-iMfolozi Park in the north east of the country, and around the Blouberg Mountains in Limpopo Province.

In the communal lands of the Paulshoek area in the Northern Cape, farmers keep Boer goats and a variety of sheep breeds including Dorper, Damara, Karakul, Persian and indigenous Afrikaner breeds (Samuels, 2013). The stock are minded by herdsman and moved between stock-posts where they are kraaled at night, and herded to their grazing areas and water sources on a daily basis (Samuels, 2013). Based on a study which involved data collection for several years using monthly interviews with 47 farmers in communal land area in Paulshoek between 1998 and 2013, Lutchminarayan (2014) found that 0.5-9.7% of goats and 2.3-19.4% of sheep were lost to predation every year. On average, 3.1 (2.4)% of goats and 5.4 (4.2)% of sheep in all Paulshoek herds were reported as being lost to predators each year

over the study period. Numbers varied significantly between years.

In the same area, Hawkins (2012) investigated the outcome of a pilot study that placed eleven 'EcoRangers' on small stock farms. Unfortunately, the pilot study did not employ an experimental approach, and there was no control. However, over the one year period from August 2011 to 2012, the rangers reported 17 livestock losses, none of which were due to wild predators. Using the figures at face value, there was a loss of one small livestock unit out of a total of 4,496 small stock units (sheep and goats) over an area of 14,852 ha (6,552 ha private and 8,300 ha communal land), i.e. 0.02% loss. The loss from an area of 3,290,790 ha in the Northern Cape, where shepherding was not used, was 6.4%, i.e. 320 times greater (Hawkins, 2012).

Studies on cattle farmers in South African communal farming areas adjacent to parks have also reported significant losses. Chaminuka *et al.* (2012) found that 32% of households close to the Kruger National Park reported livestock predation, compared to 13% in more distant households. Based on the reported average herd size and losses of cattle owning households, the study found that 8% of cattle were lost to predation in the study area. These were attributed to nocturnal raids by lions. Farmers in this area were frustrated with the slow response of the authorities in repairing park fences, and wanted to be allowed to kill predators.

In another study of communities near Kruger National Park, in the Mhinga District, Limpopo Province, Sikhweni & Hassan (2013) reported cattle losses to predation to be 11% of stocks. Both livestock predation and disease were attributed to the wildlife from the park. Without efficient game proof fencing and compensation schemes, the costs of owning livestock were claimed to outweigh the financial benefits to farmers. Measures to provide protection against livestock predation and wildlife-livestock disease transmission will greatly reduce livestock losses and in turn enhance the welfare of this group of farmers.

Similarly, people living around the Hluhluwe-iMfolozi Park (HiP) also complain of high levels of predation (Gusset *et al.*, 2008). An electrified fence that separates the park from the densely human populated surroundings encloses HiP; however, African wild dogs and other large carnivores are notoriously difficult to contain within the

perimeter fence. The human population around HiP consists of villagers on communal land and farmers on private land whose livelihoods largely depend on livestock and ranched wildlife. Gusset *et al.* (2008) interviewed 165 villagers about introducing more African wild dogs to the park. Members of the village communities around the park apparently continue to persecute them outside HiP, despite formal legal protection. Similar results have been obtained in recent comparable studies on African wild dogs in many parts of Africa (Kock *et al.*, 1999; Breuer, 2003; Davies & Du Toit, 2004; McCreery & Robbins, 2004; Dutson & Sillero-Zubiri, 2005; Lindsey, Du Toit & Mills, 2005).

Apart from the studies around protected areas, there is little reliable information on the level of depredation of livestock in communal land areas more generally. Given the findings of decreased predation rates with increasing distance from parks (protected areas) (Thorn *et al.*, 2013; Constant, 2014), it is possible that losses in the areas away from parks are considerably lower. Studies of these areas would make an interesting comparison with those of commercial farmers, given the differences in methods of livestock husbandry. Some preliminary efforts have been made. One study of a small sample of 19 commercial and 23 communal farmers in Limpopo, found that commercial farms suffered greater losses of livestock than communal farmers in the same area (1.4% vs 0.63%), but that communal farmers lost more cattle to leopards because of where they had to graze (Constant, 2014). A larger study involving a survey of 277 livestock farmers in seven different communal areas across South Africa, found that reported rates of predation were highly variable between locations, and ranged up to about 5% of cattle and up to about 20% of sheep and goats (Hawkins & Muller, 2017). The farmers claimed to rely more heavily on stock protection methods such as herding, corrals, guardian animals and bell collars than the use of lethal methods. This might be expected given that in a communal setting, farmers are more likely to gain from stock protection. However, it is also unsurprising given that non-lethal methods are not complicated by issues of legality. The latter is corroborated by the fact that many farmers expressed a wish to control predators using lethal methods and for governmental and non-governmental authorities to provide assistance with killing predators. This suggests that lethal methods are still perceived to

be essential by many. Unfortunately, neither Constant (2014) nor Hawkins & Muller (2017) used random sampling methods, so both would have been prone to bias, and apart from sampling issues, these survey methods would also be prone to overestimation of losses and underestimation of the use of lethal methods. In the latter study, the interviewees were participants of Conservation International's so-called 'Meat Naturally Initiative'. These studies nevertheless point to the fact that thorough research is needed in order to generate a clear understanding of actual rates of predation, farmer practices and the relationships between these and other environmental and socio-economic factors.

VARIATION IN LIVESTOCK DEPREDATION

The statistical distributions of stock depredation estimates are also important to consider, inasmuch as this can be done given the reliability of the data. In general, surveys suggest that most farmers experience very few losses, some experience modest losses and a few unfortunate farmers experience high losses for any given survey period (usually one or two years). For example, in Limpopo province, the proportion of stock holdings reportedly predated per farm had a skewed distribution with a median of 1.23% (25th percentile = 0%, 75th percentile = 5.75%). Some 17% of farmers reported high losses of 10–51% and one reported a loss of 89% (Thorn *et al.*, 2013). It is unknown whether this type of pattern persists spatially or whether farmers will experience differing predation levels in other years.

Spatio-temporal patterns in predation are likely to be governed by both stochastic factors, such as rainfall and drought, and deterministic factors, such as vegetation, distance to protected areas or towns, stock type and management practices. If stochastic factors dominate spatio-temporal patterns, then it is reasonable to use the average as an estimate of the level of losses. If not, i.e. if a few farms are consistently the sufferers of high predation rates, then the summary statistics must be very carefully interpreted.

There has been considerable effort in the international and local literature to unravel the factors that influence predation rates. Several anecdotal accounts and statistical analyses have found that inter-annual variation

in predation levels are influenced by rainfall, with most finding increases during drought and low rainfall seasons (Butler, 2000; Beinart, 2003, in Nattrass *et al.*, 2017; Bailey & Conradie, 2013; Badenhorst, 2014), and others finding a positive relationship with rainfall (Patterson *et al.*, 2004). The explanation for these and other temporal patterns is usually linked to the availability of wild prey (e.g. Patterson *et al.*, 2004; Mishra *et al.*, 2003; Bagchi & Mishra, 2006).

Spatial patterns tend to be influenced by factors such as broad habitat types, topography, land use, distance from protected areas and human settlements (Stannard, 2003, Thorn *et al.*, 2013, Constant, 2014). Studies seem to suggest that there is a higher level of risk of predation by apex predators closer to protected areas which act as source areas (e.g. Minnie, Boshoff & Kerley, 2015), whereas the risk of predation by medium-sized predators such as jackal increases with distance from protected areas (e.g. Thorn *et al.*, 2013), probably due to the absence of apex predators ("mesopredator release" - see chapter 8) as well as depressed densities of free-ranging wildlife.

Anthropogenic influences are clearly a strong risk determinant. In Limpopo Province, the risk of leopard predation on livestock was found to be most significantly influenced by distance to villages (contribution = 30.9%), followed by distance to water (23.3%), distance to roadways (21.2%), distance to nature reserves (15.4%) and elevation (9.2%; Constant, 2014). In the communal land areas, predation of cattle by leopards was found to be higher in the dry season when farmers were forced to take their cattle to the mountainous areas where leopards were present. Breeding was reportedly less seasonal on communal lands, which meant births were also taking place while the cattle were in these risky areas.

Van Niekerk (2010) found considerable geographic variation in small stock predation within and between provinces which suggest that biome types may play an important role. Their estimates suggest that predation rates are particularly high in the Karoo. This could well be linked to the very large farm sizes in this biome, where human presence would be lower. If this is the case, then the perception that predation rates have been increasing may also be linked to the trend for consolidation of farms in the Karoo, which ironically has occurred in order to maintain viability of farming as subsidies have diminished and employment costs have risen.

At a local scale, there is also likely to be some degree of variation between farms due to habitat which may make some farmers more vulnerable to predation losses than others (Minnie *et al.*, 2015). For example, Conradie & Turpie (2003) found that Karoo farmers recognise the different risks associated with different habitats. They tend to keep their ewes with young lambs or kids in the open plains and valleys (“vlaktes”) and larger animals on the hillsides (“rantjies”), because the latter provide suitable habitat for predators such as caracal. Indeed, many studies have found that landscape features such as steep, rocky slopes (Stahl *et al.*, 2002), cliffs (Jackson, 1996), water bodies (Michalski *et al.*, 2006) and distance to riparian corridors and forested areas (Michalski *et al.*, 2006; Palmeira *et al.*, 2008; Thorn *et al.*, 2012) have an influence on livestock predation rates. If these factors are indeed significant, they are likely to be reflected in farm prices in the commercial farming areas.

PREDATION LOSSES IN RELATION TO OTHER THREATS

Livestock and game farmers face a range of threats, including poisoning, theft, disease and drought. For example, over 600 species of plants are known to cause poisoning of livestock in southern Africa. Livestock losses due to plant poisoning have been estimated to amount to some 37,665 cattle (10% of expected cattle deaths) and 264,851 small stock per year (Kellerman *et al.*, 1996), at a cost to the industry of about R150 million (Kellerman *et al.*, 2005, Penrith *et al.*, 2015).

Figures from the South African Police Service’s National Stock Theft Unit (SAPS) indicate that around 15,000 – 16,000 cattle, 20,000 – 24,000 sheep and between 8,000 and 14,500 goats are stolen annually

(NERPO, 2009). However, based on survey data, Scholtz & Bester (2010) estimated that these numbers are probably much higher (Table 3.3), with a large proportion being stolen in communal land areas. Sheep suffered a higher proportion of losses to stock theft compared to other livestock. Nevertheless, mortality was found to be several times higher than stock theft. Unfortunately their survey did not distinguish depredation from other causes of mortality.

Scholtz & Bester (2010) argued that stock theft, problem animals and ‘vermin’ were the main reasons for the decline in livestock farming over the previous decade. Although seldom investigated in this body of literature, it is likely that the introduction of social welfare grants and changing culture have also played a significant role in the communal land areas, and that stringent labour laws have played a major role in private land areas. If factors other than predation are the primary cause of livestock declines, then this potentially diminishes the importance of the predation issue. However, it can also be argued that predation losses are putting further pressure on an increasingly vulnerable sector.

According to commercial small livestock producers, the three main threats that they face are drought, theft and predators (Stannard, 2003; De Waal & Avenant, 2008). Among the sample of mainly mixed and game farmers interviewed by Thorn *et al.* (2012), 32% of respondents considered poaching the most costly source of economic loss, followed by drought (30%), predation (19%), fire (11%) and game or livestock diseases (8%).

In communal areas, the overall losses, including from other causes, are particularly high. Around the Kruger National Park, the predation losses of 8% reported by Chaminuka *et al.* (2012) added to the reported 12.7% of cattle that died from disease, while the losses of 11% in Mhinga District were in addition to losses to disease

Table 3.3. The number of animals that die or are stolen annually on a national scale in South Africa, estimated from the results of the survey on private and communal land. Source: Scholtz & Bester (2010).

Land type	Cattle		Sheep		Goats	
	Dead	Stolen	Dead	Stolen	Dead	Stolen
Private	177 120	9 846	439 350	143 550	1 900	300
Communal	259 600	66 550	56 225	59 800	40 950	9 750
Total animals	436 720	76 396	495 575	203 350	42 850	10 050

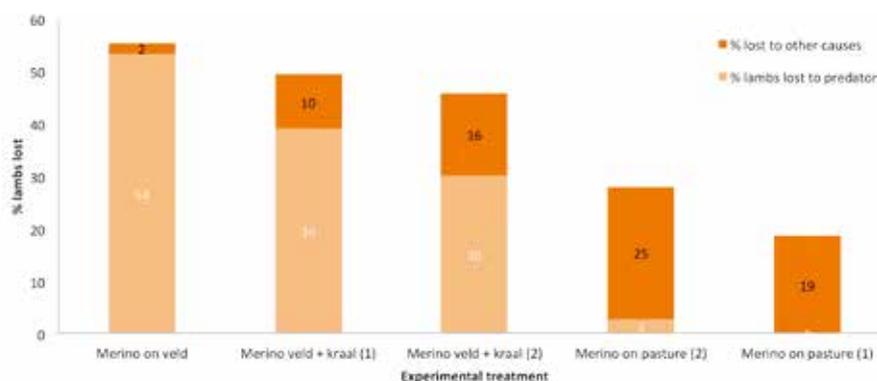


Figure 3.4. Percentage of lambs lost to predation or other causes before weaning in five experimental areas of the Free State Wool Sheep Project (Data extracted from Strauss 2009).

(23%) and theft (3%). In Limpopo, while predation was the main cause of livestock losses (65%), significant numbers were also lost to disease (18%), theft (13%) and accidental deaths (3%), with no significant differences in the proportions of these between communal and commercial farms (Chaminuka *et al.*, 2012).

In light of the above, one of the shortcomings of estimates of predation impacts is that they do not consider the counterfactual: what losses would have been incurred in the absence of predators? At the very least, it might be expected that there would have been some natural mortality among the animals that had been predated, especially given that these are often the weaker or sicker animals. While no work has been done to answer this question *per se*, perhaps the best indication comes from work done on an experimental farm set up by government, academic institutions and the wool industry. Strauss (2009) analysed predation data from the Free State Wool Sheep Project established in 1998. Set up to compare different production strategies, it was realised fairly early in the project that predation by jackal, caracal and stray dogs was a significant problem. The findings showed that both Merino and Dorper sheep suffered heavy losses when kept in the veld, though these appeared to be ameliorated by kraaling at night. Predation losses were close to zero for the sheep kept on planted pastures for part of the year (Strauss, 2009, Figure 3.4). Overall Merino post-weaning losses to predation ranged from 6.7 to 26.3% per annum (average 18.6%), compared to 0.9%, 3.0% and 1.3% losses to disease, metabolic disorder and accident, and theft, respectively. Most of the post-weaned losses were 4-12

months, but older, and especially pregnant, ewes were also vulnerable. The results of the Strauss (2009) study suggest that when management actions reduce the risk of predation, a substantial proportion of the avoided predation losses become lost to other causes. Indeed, in their study, a 23% reduction in predation losses resulted in a net reduction in overall losses of 10%, and 51-54% reduction in predation led to net reductions in losses of 27-37%. This substantiates our hypothesis that a 10% reduction in predation will not result in a 10% reduction in losses.

FARMER'S OPTIONS AND RESPONSES

Farmers can opt to try and eliminate predators through lethal methods, or to protect their stock from predators using non-lethal methods, or they can use a combination of these. Lethal methods include shooting, hunting with dogs, setting snares, trapping and poisoning (Arnold, 2001; Moberly, 2002; van Deventer, 2008; Van Niekerk *et al.*, 2013). Shooting can be done by the farmers themselves or by professional hunters that are paid by the farmer. Hunting with dogs is also effective, but is more costly because of the costs of acquiring, training and maintaining the dogs. Poisoning is cheap and easy, but it is not species-specific and results in the unnecessary and painful deaths of non-problem animals (See Chapter 4 for further consideration of ethical issues). A variety of traps is also used, including cages, boxes, leg-hold traps and snares. Use of traps is also widespread and considered to be cost-effective, but is somewhat more labour-intensive if farmers are concerned about preventing unnecessary suffering, as the traps have to be checked regularly. Legal

perspectives on the use of lethal methods are covered in more detail in Chapters 5 and 6. This includes not only the methods but the species targeted. Cheetahs, leopards, lions, spotted hyaena, brown hyaenas and African wild dogs are protected under the Threatened or Protected Species Regulations (ToPS) which were introduced in 2007 under the National Environmental Management: Biodiversity Act (NEMBA), Act 10 of 2004.

Non-lethal methods include kraaling of small stock (or indoor housing), use of herders, predator-proof fencing, bells, guard dogs or protective collars. In the past, farmers invested heavily in jackal-proof fencing to deter predators from entering camps. These fenced areas need to be checked continually for breaches, but the system works well if managed properly. Electric fencing, which was introduced later, has been particularly effective in controlling jackals (Heard & Stephenson, 1987). However, without the subsidies of the past, fences are now costly to erect (Snow, 2006), and include ongoing investment in labour time which is becoming more expensive. Even so, they are still considered to be cost-effective (Badenhorst, 2014).

The practices of herding and kraaling diminished in commercial rangelands as boreholes and affordable fencing allowed farmers to create relatively predator-free camps, and as ideas about veld management practices changed (Davies, 1999). Minimum wages have also increased since the 1990s, and labour legislation has also made it difficult to lay off staff. As a result, farmers have tried to minimise their use of hired labour and to use other methods, including sheep dogs. However, human presence in the lambing (or calving) area is still considered by some to be by far the simplest and most effective way of deterring predators in the Karoo, and some farmers have returned to this tradition (Davies, 1999).

The use of guarding animals has been posed as a labour-saving solution to protecting livestock, and has been tested with varying success. Anatolian dogs are the most popular choice, but are expensive to obtain and are only effective against smaller predators (Snow 2006). Nevertheless, the results of trial programmes in Namibia, Australia and South Africa suggest that this is a highly effective method (Marker, Dickman, Mills & Macdonald, 2005; van Bommel & Johnson 2011; McManus, Dickman, Gaynor, Smut & MacDonald, 2015).

One of the main drawbacks is that the dogs do need to be fed and monitored.

Apart from hunting with dogs, the costs of lethal methods as currently practiced are generally relatively low, whereas the costs of non-lethal methods vary greatly (Figure 3.5). Most collars and warning systems are cheap, and might offer some level of protection that makes it worthwhile, but some more sophisticated systems are highly expensive. These still rely on an appropriate response by the farmer. Electrical fences are costly to put up, but costs are relatively low over five years, and are comparable to guard animals. The costs of guard animals over 5 years were similar to the costs of professional hunting. Human guards are the most expensive option overall (Figure 3.5).

It is not surprising therefore, that most commercial farmers still employ lethal methods in their efforts to reduce predation risk. Nevertheless, the majority of farmers that engage in predator management do use some non-lethal methods as well. Predator control in general is more prevalent among small stock farmers than cattle farmers and game farmers. Badenhorst (2014) found that the proportion of cattle farmers engaging in any form of predator control ranged from 37% and 66% in six provinces (average 52%), but was only 4% in the Eastern Cape. Most small stock farmers, on the other hand, engage in practices to reduce predation risk. Between 60 and 90% of small-stock farmers in 5 provinces (average 74%) practice lethal methods, while 44-87% (average 67%) practice non-lethal methods (Figure 3.6).

Shooting has tended to be the most popular option on both small-stock and cattle farms (Figure 3.7), although it is no longer considered as effective as it used to be (B. Conradie, pers. comm.). Poisoning, despite being illegal was still commonly practiced at the time of the surveys, particularly in the Northern Cape.

Herding and kraaling are the most common non-lethal methods used to protect wildlife against predators, both among small-stock and cattle farmers (Figure 3.8).

In Limpopo Province, Thorn *et al.* (2013) found that lethal and non-lethal methods were practiced at 47% and 79% of farms, respectively (35% using both), and 15% of farms (all extensive game farmers) used neither. Non-lethal methods included fenced enclosures, moving potential prey animals to open areas with a lower risk

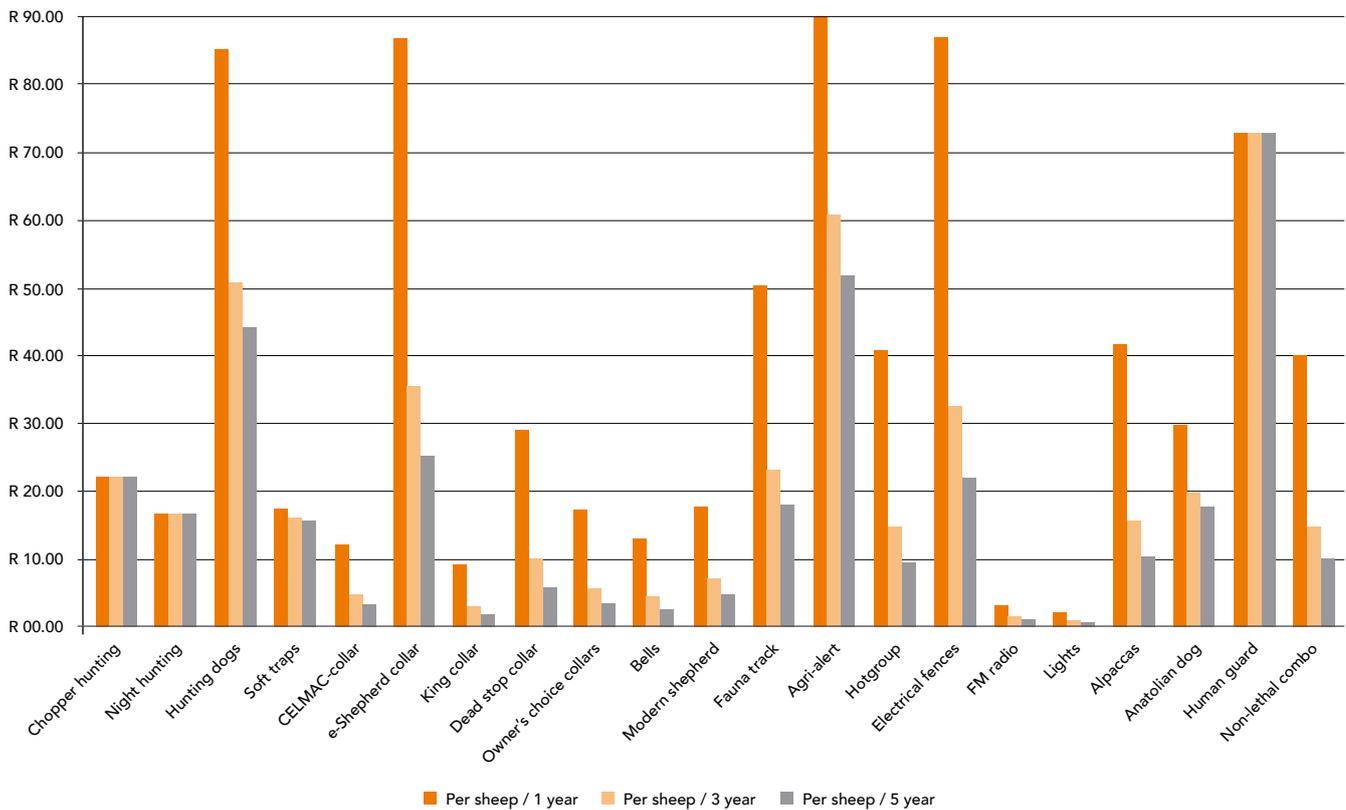


Figure 3.5. Relative costs per ewe of lethal and non-lethal methods for a typical Karoo farm of 6000 ha with 1000 ewes in three herds (dry, lambing and replacement). Source: <http://www.pmfsa.co.za/home/detection-prevention>.

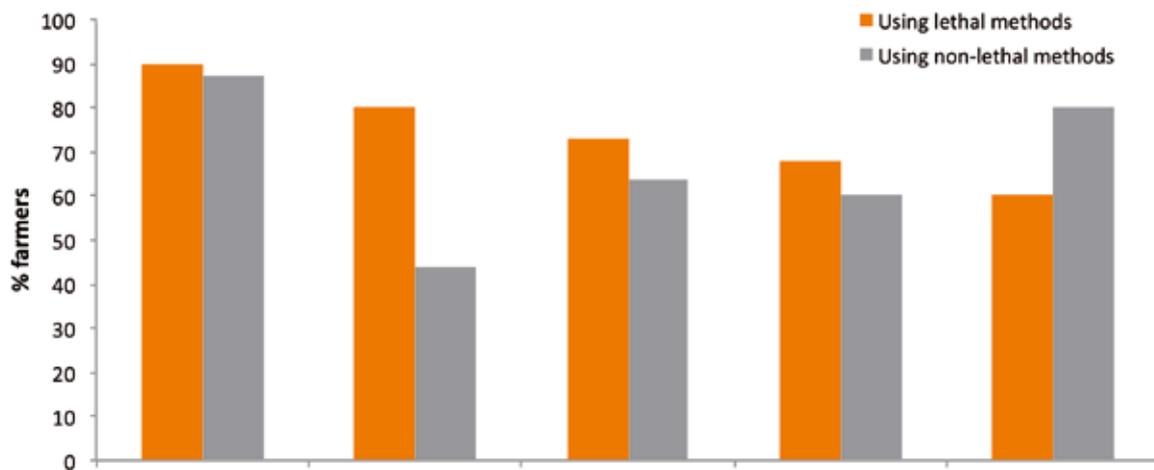


Figure 3.6. Percentage of small stock farmers using lethal and non-lethal methods in 5 provinces (Source: van Niekerk, 2010).

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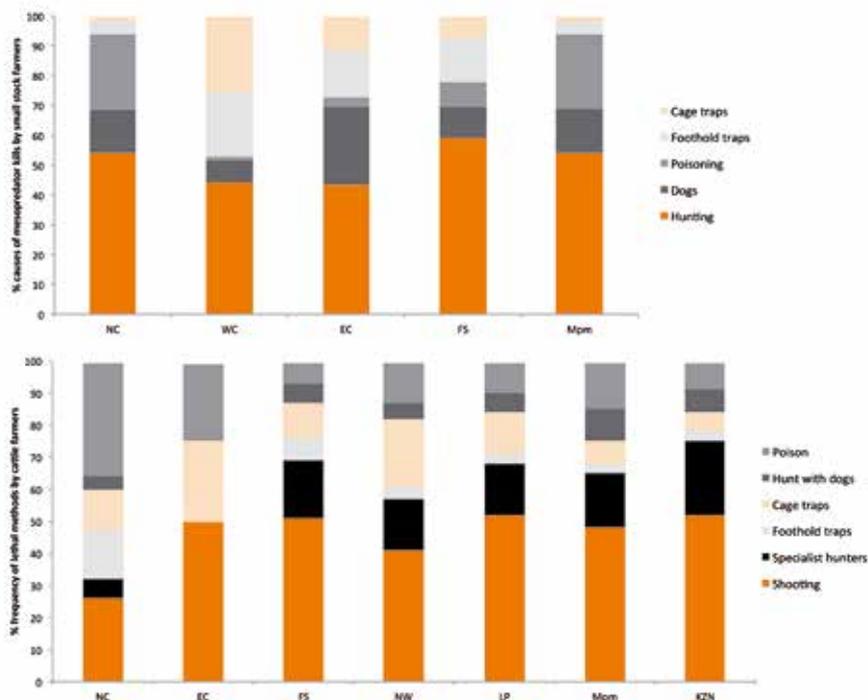


Figure 3.7. Indications of the relative use of different types of lethal methods on small-stock and cattle farms, based on data in van Niekerk (2010) and Badenhorst (2014).

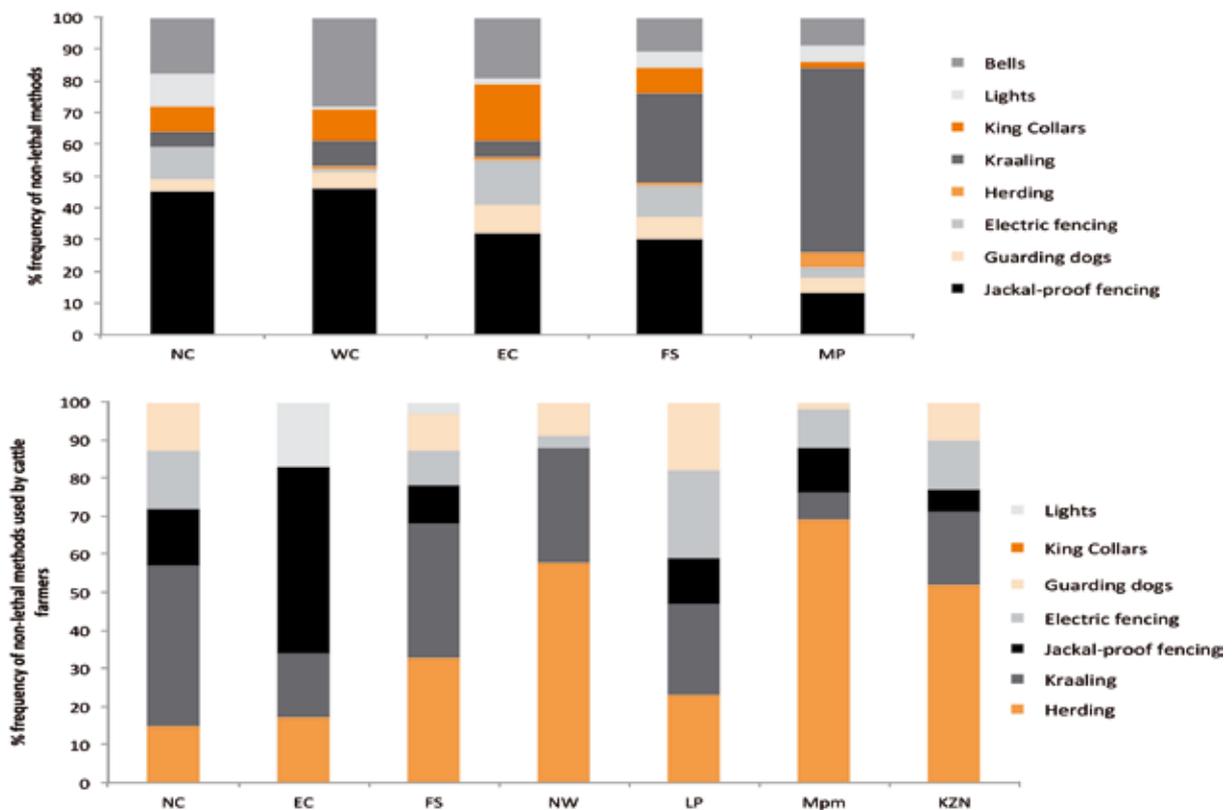


Figure 3.8. Indications of the relative use of different types of non-lethal methods by small stock farmers (above), and cattle farmers, based on data in van Niekerk (2010) and Badenhorst (2014).

Table 3.4. Expenditure on lethal and non-lethal measures by cattle farmers. Source: Badenhorst (2014).

Province	Expenditure on lethal measures R per head	Expenditure on non-lethal measures R per head
Northern Cape	R4.21	R25.13
Eastern Cape	R0.39	R0.89
KwaZulu-Natal	R4.13	R22.87
Free State	R6.72	R13.95
Mpumalanga	R4.47	R12.29
Limpopo	R8.94	R10.20
North West	R6.04	R7.67

of predation and natural anti-predator adaptations (stocking native, predator-adapted breeds and not dehorning livestock). In the North West Province, 67% of farmers practiced lethal control of carnivores (Thorn *et al.*, 2012), while 63% used non-lethal methods, and 32% used both. A greater range of lethal methods was reported, including poisoning and trapping. Non-lethal deterrents included protective enclosures, guard dogs and human guards. Some 16% of farmers did not use any methods (Thorn *et al.*, 2012). In this context it is important to note that there has also been a rise in “weekend farmers” (Reed & Kleynhans, 2009; Wessels & Willemse, 2013) who may be less inclined to take action against predators.

Thorn *et al.* (2013) found that lethal control tended to be practiced to a much greater extent by certain cultural groups, which was a much greater determinant of its likelihood than actual financial losses. They found that the odds of a farmer practicing lethal control were about 19 times greater among Afrikaans-speaking farmers and about 7 times greater among English-speaking farmers, compared to Setswana-speaking farmers. Lindsey *et al.* (2005) also found that Afrikaans-speaking farmers and older people were less tolerant of carnivores. However, these studies need to control for factors such as differences in what people were farming before any real conclusions can be drawn.

Few studies have obtained information on the expenditure by farmers on predator control. Among cattle farmers, who suffer relatively low losses compared to other stock types, average annual expenditures in

each province ranged from R0.39 to R8.94 per head on lethal measures, and from R0.89 to R25.13 per head on non-lethal measures (Table 3.4; Badenhorst, 2014). There was no relationship between expenditure and the percentage losses in each province. In the North West Province, expenditure on these measures was about a quarter of the value of the losses incurred (Badenhorst, 2014).

Farmers in communal areas have fewer options in their response to predators, and cannot resort to the option of fencing and extermination of predators from fenced camps. Herding and kraaling are the most common response in these areas, and form very much part of cultural tradition in these pastoral areas. Killing predators is less likely to be effective in communal rangelands but is still pursued. This is consistent with communal areas in other parts of the world. To some extent this is driven by socio-economic circumstances. Where livestock are the main livelihood strategy, people are more likely to be antagonistic towards wild predators (Dickman, 2010). Conversely, wealth, income diversification and social reciprocity within families and communities may provide adequate coping mechanisms for buffering the impacts of damage-causing animals (Naughton-Treves *et al.*, 2003; Naughton-Treves & Treves, 2005). For example, perceived high rates of depredation in Nepal by snow leopards *Panthera uncia* encourage pastoralists in Asia to consider the extermination of the snow leopard as the only solution (Oli *et al.*, 1994).

COST-EFFECTIVENESS OF PREDATOR MANAGEMENT

Farmers undoubtedly make their choices regarding predation management on the basis of perceived cost-effectiveness as well as affordability. There is little scientific evidence, however, on the relationship between investment in these practices and the losses avoided, or the relative cost-effectiveness of different lethal and non-lethal methods. This will require experimental or quasi-experimental analysis, both of which rely on a substantial amount of monitoring data. It is clear that the sector urgently needs to invest in such co-ordinated research. There have been a handful of studies in South Africa that have examined the effectiveness of different lethal and non-lethal methods, including the cost-effectiveness of these methods. These studies suggest that a significant proportion of both lethal and non-lethal methods are not very effective.

For example, analyses of hunting club records, which span multiple farms over multiple years, have suggested that caracal killing actually increased subsequent livestock losses when compared to farms where fewer caracals were killed (Bailey & Conradie, 2013; Conradie & Piesse, 2013), whereas culling vagrant dogs would reduce the likelihood of future losses. Some caution needs to be exercised in interpreting these findings and the cause and effect relationships. Van Niekerk *et al.* (2013) found that use of professional hunters was ineffective, and that kraaling small stock at night in the Western Cape had a significant positive effect on the level of predation on a farm. The latter was thought to be due to the fact that damage-causing animals

learn to infiltrate closed areas and cause major losses, especially where fences are not up to standard. However, a high level of success was experienced when non-lethal methods are used in combination or in rotation with one another, probably due to the adaptability of predators (van Niekerk *et al.*, 2013). In a study of cattle farms in the North West Province, Badenhorst (2014) found that specialist hunters, hunting with dogs and guarding animals, all had a positive relationship with occurrence of predation, while other lethal methods had no significant effects. Even if this signifies a retaliatory response, it does call into question the effectiveness of these methods. Nevertheless, limited conclusions can be drawn from these studies, and the issue is examined in more detail in Chapter 6.

The economics of lethal versus non-lethal predator management was explored by McManus *et al.* (2015) in a short (3-year) experiment conducted on 11 farms in the Swartberg region of the Western Cape Karoo (McManus *et al.*, 2015). The farmers in the study continued to use lethal controls in the first year (mostly gin traps, except for two farms that used gun-traps and hunting, respectively), then switched to guardian alpacas and dogs for the following two years. The study results suggested that non-lethal controls were significantly cheaper and four times as effective as lethal controls (Table 3.5). These findings agree with those of other studies. For example, in a study of 10 farms, Herselman (2005) found that the percentage of lambs caught before weaning decreased from 7.6% to 2.6% two years after the introduction of guard animals. However, a follow-up study showed that many of the farmers in the McManus study had resorted to using lethal methods again (<http://www.travel-hack>).

Table 3.5. Results of a three year experiment on 11 Karoo farms of the cost of protection and livestock predation. Source: McManus *et al.*, (2015).

	Cost of protection per head of stock	% losses	Value of losses per head of stock	Total cost
Year 1: Lethal control	\$3.30	13.6%; (4.0–45%)	\$20.11	\$23.41 (3.552–69.290)
Year 2. Non-lethal control	\$3.08	4.4% (0.1–15.0%)	\$6.52	\$9.60 (1.49–28.82)
Year 3. Non-lethal control	\$0.43	3.7%: (0.1–14.2%)	\$5.49	\$5.92 (0.72–21.62)

com). If the conclusions about cost-effectiveness were accurate (see Table 3.5), then this suggests that the choice of methods was also driven by other factors, such as the emotional response to predators that harm their livestock or a cultural affinity to the use of lethal methods.

Another issue that should be taken into consideration is the impact of predator control on grazing resources, through its indirect impact on other grazers. The extermination of predators in the Karoo is thought to have been the reason for irruptions of rock hyrax that have occurred in the past leading to significant damage to vegetation (Thomas, 1946; Kolbe, 1967; Kolbe, 1983 in Davies, 1999). However, these relationships are still poorly understood.

ECONOMIC IMPACTS OF LIVESTOCK DEPREDATION

The presence of predators in rangelands translates into two types of costs for farmers: the cost of taking action to reduce the threats to livestock, and the losses due to livestock depredation. Both of these are direct costs that impact on the farmer's bottom line, or profits. Farmers' profits form part of the value added to agricultural GDP, along with the wages paid to their labour and taxes paid to government. Thus an impact on farmer profits translates into an impact on agricultural GDP, being a measure of aggregate income in the sector. Furthermore, the expenditure by farmers on their inputs ("intermediate expenditure") generates income in other sectors, such as manufacturing and transport. Impacts on farm-level production may also be felt through the value chain, affecting feedlots, abattoirs, tanneries, wholesalers, retailers, processors and the like. Therefore negative impacts on farm output could also have knock-on effects in a variety of other sectors and subsectors.

Recent studies of predation losses in South Africa's commercial farms are relatively comprehensive in their coverage, and suggest that aggregate losses of livestock amount to R2.8 billion per annum, with losses of at least R2.34 billion to small stock farmers (R1.39 billion in 2007), and R479 million to cattle farmers (R383 million in 2012). In addition, losses from South Africa's 11 500 game farms (DAFF 2016) and from small-scale and communal farming areas could also be substantial, and likely to bring the total to over R3 billion. Estimates still vary, however. For

example, Thorn *et al.* (2012) estimated total losses of R68 million to all farm types in North West Province, whereas Badenhorst (2014) estimated losses of R84 million for cattle farms alone in the same province. McManus *et al.* (2015) also questioned the disparity between estimates of Statistics South Africa (2010) based on the 2007 agricultural census, and those of van Niekerk (2010), which were nearly eight times higher. Nevertheless, van Niekerk was conservative in his estimates of value: whereas some authors advocate using the value of the "finished product" (*sensu* McInerney, 1987; Moberly, 2002), i.e. the income that would have been derived from the animal had it survived, van Niekerk used the replacement value of animals lost - (R600 for young stock and R1000 for older animals).

The Agriculture, Forestry and Fisheries sector contributed R94.4 billion to GDP in 2016, or 2.4% of GDP (Contribution to VAD has been 2-2.1 from 2010 to 2015, but rose to 2.4 in 2016 DAFF, 2017). Agriculture makes up about 80% of this (Stats SA, 2013). Animal production makes up about 49% of the gross value of agriculture production, with crops and horticulture making up the balance. Free-ranging livestock contributed about 33% of animal production value and therefore about 16% of gross agriculture production value. The gross production value of free ranging livestock was about R39.75 billion in 2016. Based on these figures, the direct contribution to GDP would be in the order of R12.3 – 14.7 billion (Lower estimate is 16% of sectoral contribution, upper estimate based on most recent estimate of multipliers for livestock products (Conningarth Economists 2015)). Overall impacts on GDP, taking economic linkages and induced spending effects into account, are about double this. Therefore losses in the formal livestock sector (~R3 billion) amount to an estimated 7.5% of its gross production value. Assuming that in the absence of predators about 50% of these animals would be lost to other causes (see above), the loss amounts to about 0.5% of the Agriculture Forestry and Fishing Sector GDP and 0.01% of national GDP, or 0.02% if multiplier effects are included. Even if game losses and livestock losses in the small scale and subsistence sectors were taken into account, and if expenditures on predator control were also included, the overall impacts would be fairly small when viewed in the context of the national economy.

Nevertheless, in a struggling economy, such losses

count, and may be important in local contexts. Livestock farming is the backbone of the economy in large parts of rural South Africa. Meissner (2013) estimated that in the region of 245,000 employees with 1.45 million dependants could be employed on 38,500 commercial farms and intensive units, with wages amounting to R 6.1 billion. This suggests that impacts on the profitability of livestock farming could affect many people involved in commercial farming.

Impacts on the viability of farming are likely to vary among different types of farms as well as individual farms, depending on their geographical and social context. Thorn *et al.* (2012, 2013) found that livestock predation losses were generally not sufficient to threaten farming livelihoods or the economies of the North West and Limpopo provinces. In the North West, predation losses amounted to a very low proportion of annual net operating profits for farms (0.22–0.29% for game farms, 0.46–0.73% for cattle farms and 0.37% for sheep farms, and only 0.2% of provincial agricultural GDP; Thorn *et al.*, 2012). Stannard (2003) felt that the predator problem was not a general threat to small livestock production in South Africa. However, van Niekerk (2010) concluded that the high losses reported on small stock farms constituted a threat to their viability. Most studies suggest that predation is highly variable, and may be a significant problem for a small proportion of farmers. In addition, game farms stocking high value ungulates might suffer disproportionately high financial losses from relatively low predation rates.

These are the areas over which farmers have (constrained) choices in the long (stock type), medium (non-lethal control practices like fencing) and short terms (lethal predator control practices like hunting). In the short to medium term, farmers make decisions about how much to invest in lethal and non-lethal control methods based on the information they have at hand. But in the longer run, if losses are persistently high, this could have an impact on the nature of farming. Where certain types of farming have become unviable, this has led to changes in land use. For example, high rates of stock theft led to a change from beef to dairy farming in KwaZulu-Natal (Turpie, 2003). Predation may also have played some role in the rapid and extensive transition to game farming that has taken place in South Africa, along with other market forces and the introduction of

legislation to encourage this activity. The impacts of these changes have not been properly studied, but they do not appear to have resulted in catastrophic losses in production or employment, and may even have had positive impacts on GDP, since game ranching tends to be more profitable than livestock farming (Bothma, 2005).

SOCIAL CONSEQUENCES

Given the above findings, it is probably true to say that the human-wildlife conflict that has arisen on commercial and communal farmlands is more of a social problem than an economic one. On commercial farms, the increasing problem not only threatens the livelihoods of the poorer farmers but is also becoming an issue of much discontent among the farming community, and leading to a fair amount of blame and antagonism among those with opposing views.

While much attention has been given to the plight of commercial farmers and the increasing difficulties that they face in the absence of government intervention, very little is known about how livestock depredation impacts on previously-disadvantaged small-scale and subsistence farming communities. While livestock production contributes very little to the formal economies of communal areas in South Africa (Mmbengwa *et al.*, 2015), they have significant social value, contributing to multiple livelihood objectives and offering ways out of poverty (Randolph *et al.*, 2007; FAO 2009; Becker 2015). In these areas, livestock may be used for meat, milk, ritual slaughter and bridal payment, and are a valuable asset as a store of wealth that can be utilized as collateral for credit in difficult times (Hoffman & Ashwell, 2001; Jones & Barnes, 2006; DAFF, 2010; Chaminuka *et al.*, 2012). Thus the loss of livestock assets has more than just a financial impact. However, it is important to note that the dependence on cattle in communal areas has diminished as a result of the increased provision of government support to poor households in the form of welfare grants, as well as a gradual change in technology and culture that also makes banking easier. Nevertheless, for those farmers that are still engaged in livestock husbandry, predation is still a real issue and a threat to this livelihood. In South Africa this threat appears to be greatest in the communal areas around wildlife parks. There is clearly a need for conservation authorities to pay

attention to human-wildlife conflict issues in these areas (e.g. see Balme *et al.*, 2010).

Studies elsewhere have found that human-wildlife conflict can have significant impacts on households, families or individuals (Hill, 2004). There are hidden impacts, defined as “costs uncompensated, temporally delayed, psychological or social in nature” (Barua, Bhagwat & Jadhav, 2013, p. 311). These include diminished states of wellbeing due to negative impacts on livelihoods and food security. Some of the problems that arise include the restriction of movement due to increased guarding effort to protect livestock from predators, the costs of pursuing compensation for livestock losses due to bureaucratic inadequacies and delays and mental stress arising from social ruptures and loss of paid employment (Barua *et al.*, 2013). Hidden costs are rarely investigated in studies involving human-wildlife conflicts (some exceptions being: Hill, 2004; Hazzah, 2006; Dickman 2008; Ogra, 2008; Inskip *et al.*, 2013).

Another hidden cost is that felt by society more generally. The impact of predator management in livestock farming areas on biodiversity also needs to be considered, since this affects society too. Farmer responses to wildlife damage are considered by many to be disproportionate or even extreme, especially by those members of society that derive a sense of wellbeing from the existence of wild nature. For example, in the 1980s, 7,000 cheetahs were killed in Namibia to protect livestock, even though reports of livestock depredation were rare (Marker, 2002; Marker *et al.*, 2003). In South Africa, the killing of leopards has also unleashed public outcry (IOL, 2011). The funding provided to non-profit organisations that promote non-lethal methods of predator control in South Africa are an expression of this publicly-held value.

CONCLUSION

It is clear from the literature that losses incurred by farmers as a result of predators are widespread and common, though highly variable across individual farms and the landscape as a whole, with losses being in the order of 3-13% of small stock, less than 1% of cattle, and losses of commercially-farmed game being intermediate. Collectively, these losses add up to billions of Rands annually, and amount to a substantial proportion of

agricultural output value, but they do need to be seen in perspective in that without predators, a significant portion of these losses might still occur due to other forms of natural mortality. Given the small contribution of this sector to GDP, the overall losses are not significant at regional or national scales. Nevertheless, they may be of local economic and social significance, particularly in the arid areas of the Karoo and in certain communal rangeland areas. In areas where farming is marginal and households are poor, high levels of predation could have significant welfare impacts and could also contribute to social disharmony.

The ecological, economic and social drivers and responses of human wildlife conflict in South Africa's private and communal rangelands and their interactions are still poorly understood. In spite of efforts to date, there is very little conclusive evidence on the factors that lead to higher rates of predation on certain farms than on others, and the degree to which patterns are consistent in time. No studies have satisfactorily determined the extent to which the level of predation risk on a farm is determined by factors under or beyond the farmer's control, partly because there is very little reliable, farm-level data on predation or anti-predator effort. No proper panel data study has yet been carried out on this issue in South Africa, but such research is in the pipeline. Such an analysis will provide better insight into the longer term distribution of predation losses among farms, the impact of predators on farm profits and viability and the returns to different anti-predator measures. Similar efforts are also needed to understand human-wildlife conflict in communal land areas.

Future studies will need to incorporate a strong social research element in order to better understand farmer motivations and responses, and will also need to consider the broader impacts of different courses of action on society as a whole. While still unknown at this stage, it is feasible that the best solution for farmers would align with the best solution for society, for example through the establishment of 'predator-friendly' production systems that reduce risk by pursuing a more natural ecological balance and returning management emphasis to stock protection measures. If so, it is a matter of understanding and addressing any institutional, informational, financial and social obstacles to reaching this solution. If this is not the case, then suitable policy instruments will need to be found that will make it worthwhile for farmers to engage in practices that are for the benefit of broader society.

Box 3.1 Important knowledge gaps

Understanding the economic and social consequences of depredation problems in rangelands has been fraught by a lack of systematically-collected data. It is only in recent years that larger scale surveys have been carried out, and that panel studies have started to be established. Future studies should include (a) large-scale, multi-disciplinary, multi-year, panel studies (i.e. involving the same farmers) that collect data on farming practices and a range of biophysical and socio-economic variables, (b) experimental and behavioural economics studies, (c) stated preference studies and (d) social and anthropological studies in order to address the following knowledge gaps:

- » Spatio-temporal patterns in predator densities and rates of predation;
- » The factors driving rates of predation, taking contextual and management factors into account, including the role of natural prey density;
- » A detailed understanding of the role of private game farms;
- » The net effect of predators taking other sources of loss into account (i.e. the counterfactual)
- » The factors driving farmers' choice of methods;
- » The level of investment and ongoing expenditure on different means of dealing with predator problems, and how this varies;
- » The effect of predation risk on the viability of farming with livestock;
- » The extent to which responses to predation risk (or risk of livestock losses more generally), including changing land use, impact on farming communities, farm income and employment, and the social consequences;
- » The role of predation risk in changing land use patterns, versus other factors such as market prices, crime and labour legislation;
- » Societal values and preferences regarding the presence and management of wildlife (generally) and predators (specifically) on rangelands;
- » The potential effects of alternative policy measures such as incentivising or subsidising non-lethal methods, fencing and eradication, or managing for more natural, free-ranging prey populations.
- » Identifying measures that would be effective in achieving desirable outcomes from a societal perspective, and the costs and benefits of their implementation.

All of these issues have been discussed in the chapter and have been researched to some extent, but none of them are very well understood.

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ETHICAL CONSIDERATIONS IN THE MANAGEMENT OF LIVESTOCK PREDATION

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INTRODUCTION

What makes the predation of livestock an ethical issue? It might not seem obvious to all that the management of predators has anything to do with ethics. However, a key element of the livestock predation issue is that it entails conflicts of interest between various stakeholders; and wherever conflicts of interest exist there are ethical implications. Without guidelines or policies for resolving conflicts of interest, conflict of another, more harmful kind can easily develop between those with competing interests. The most obvious conflict of interest in this situation is that between livestock owners and predators. With losses of livestock due to predation in South Africa estimated to cost more than a billion rand annually (Kerley et al., 2017, but see Chapter 3 for revised figures) livestock owners clearly have economic interests they would want to protect. Predators have an interest in feeding themselves and their young, in avoiding injury or disability and in their survival. Our ethical dilemma consists in deciding on what sort of policies we need to apply in order to decide which (if any) of these interests carry more moral weight and deserve our protection, or, at least, how best we can try to ensure some fair balance between the competing interests. (Note: In this chapter 'we' and 'us' are mostly used to refer to humankind in general. In some cases, such as this use of 'we', the assumed agents might not be humankind as a whole, but rather a more circumscribed and specific group, such as those who are interested in formulating appropriate policy for livestock management. The context should be sufficient to assist the reader to understand how these words are used).

THE situation is further complicated by the fact that there are other stakeholders, who also have interests in and differing moral visions regarding the management of predators. Some of these are societal stakeholders. Local communities, who depend on livestock farming for the strength of their economies and their own livelihoods, may side with farmers; other citizens, deeply concerned about the preservation of nature and biodiversity, may choose the side of the predators; those with a stake in eco-tourism have different interests

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from those in the meat or wool industries. Furthermore, future generations of people may be said to have an interest in our actions in the present, especially in terms of the preservation of biodiversity and the environment more generally. Setting aside human interests, there are other species that must also be taken into consideration. For instance, the loss of predators in an area can have an impact, negative or positive, on the well-being or survival of natural prey species, other smaller predators, other animals, as well as on vegetation. Thus, there are many different stakeholders, with a variety of interests, many of which are in competition with others, that need to be taken into account in trying to formulate policy on predator management. Policy makers need to weigh up competing interests and moral obligations in seeking the best overall outcomes for all stakeholders.

This is why this chapter on ethical considerations with respect to the management of livestock predator impacts is necessary. In situations such as these, where the interests of many stakeholders are relevant and in which our moral duties towards different stakeholders come into conflict with one another, it is important that we reflect very carefully on what our ethical priorities are. To do this, some engagement with various moral theoretical perspectives and notions is necessary, as these provide the conceptual tools that enable us to fully appreciate the nature of the competing interests and ethical obligations that are of relevance, as well as with some direction on how to balance interests and obligations. While it is clearly important that any interventions recommended by policy makers should ordinarily comply with existing legislation and regulations – unless they are themselves unethical – the law alone is not able to provide answers to all of the complex ethical issues that arise in situations such as these. This is where the discipline of applied ethics can come to our aid in providing intellectual resources that can help us make the best decisions.

As a starting point, any ethical analysis of a complex situation requires the identification of all relevant stakeholders as well as their interests. It also requires identifying all of our ethical obligations towards these various stakeholders, recognising that these will often come into conflict with one another. The problem here is that there is no consensus on which stakeholders should be taken into account and what kinds of moral

obligations we have. Some, for instance, might claim that only human beings have interests, at least of the kind that matters. So, they might think that our work is done if we have found a way to balance the competing human interests in cases such as this. There is even less agreement on what kinds of moral obligations we might have. Most will likely acknowledge a moral obligation to protect the livelihoods of people, but some also think that we have moral obligations towards individual animals, and some even claim that we have duties towards species, ecosystems and even the biosphere as a whole. Some engagement with these and other relevant overarching moral questions is necessary for our ethical appraisal to be thorough, comprehensive, robust and plausible.

Ultimately, though, our ethical analysis needs to go beyond merely weighing up competing interests and moral obligations in an abstract, theoretical sense. It needs to consider the various options that exist in terms of actions that can be taken to address the conflicts of interest. In the case of livestock predation this necessarily entails engaging in an ethical analysis of all of the possible options available for managing livestock predator impacts. The moral implications of these various methods need to be understood by policy makers. How effective is each strategy? What sorts of harmful consequences does each strategy result in and for which stakeholders? Which methods result in the least harm and take into account all important interests? Furthermore, it is important to provide policy makers with a set of guidelines or basic principles that can be applied to choose the most appropriate strategy in each specific situation. These guidelines ought to assist them in making the best ethically justifiable decisions possible.

The body of this chapter consists of four main sections. In section 1, attention is given to a theoretical consideration of our moral obligations to other humans. Social contract theory is introduced as a helpful approach to dealing with situations in which there are many competing interests and where policies need to be devised that can resolve conflicts. The question of moral obligations to future generations is also addressed. In section 2, the focus is on our moral obligations to other living entities and nature. First individualist approaches to our duties to non-humans are introduced. These

include animal welfarism, the animal rights/liberationist school and biocentrism. Thereafter, the holist or ecocentrist approach is presented. The section ends with a discussion of the special value that holists often accord to predators. Section 3 focuses on a few pertinent ethics lessons to be learnt from the history of predator management in South Africa. In the fourth and final section, several principles for the ethical analysis of current methods of predator management are proposed, explained and applied.

OUR MORAL OBLIGATIONS TOWARDS OTHER HUMANS

Few would likely question the claim that we have moral obligations towards one another as human beings. Thus, it is fairly uncontroversial that it is necessary for our society to find some way of settling the disputes that arise in the conflicts of interests between various persons and groups of persons with respect to the livestock predation issue. Ultimately what is needed is a morally justifiable approach for management of competing interests and ideals. Where our focus is on the ethics of policies, laws, regulations or guidelines, what moral theoretical resources might be most useful to us? On what basis can we distinguish between laws or policies that are ethically sound and those that are not?

Social contract theory

One very valuable approach in this respect is grounded in what is known as 'social contract theory'. Thomas Hobbes (1588-1679) is one of the philosophers whose ideas most significantly influenced social contract theory. He sees morality (including the law) as a necessary solution to a practical problem. He thinks that it is a fundamental part of human nature for people to be essentially self-interested. Yet, if everyone were to pursue their self-interest at all times, without consideration of any others, our lives would be quite unbearable. In fact, we would live in a very dangerous world, always having to try to protect ourselves from others who would take our belongings and harm or even kill us, so long as it was in their self-interest. Furthermore, we would be completely unable to work co-operatively, which would make our life experiences considerably less rich and meaningful. He therefore argues that it is in our collective self-interest

to have morality, laws, and some form of government to enforce the laws to ensure the best possible existence. Hobbes also believes that we are reasonable beings, and are thus able to recognize that it is rational and in our best interests overall to submit ourselves to morals and laws that will prevent us from constantly harming one another and that will enable us to reap the benefits of co-operation. So, he thinks it is rational for us to enter into an assumed social contract with one another in which we agree to certain limitations on our freedom to act selfishly and with impunity, because that is ultimately in our individual best interests (Friend, n.d.). More modern proponents of social contract theory offer many more nuanced and sophisticated versions of this basic idea. What they have in common is the assertion that the moral rules (and laws) of our society should be those that rational agents would agree to. T.M. Scanlon famously expresses it as follows: "It holds that an act is wrong if its performance under the circumstances would be disallowed by any set of principles for the general regulation of behaviour that no one could reasonably reject as a basis for informed, unforced general agreement" (Scanlon, 1999). In other words, the principles we apply to regulate behaviour should be those reasonable people would agree to.

This brief account of social contract theory will suffice for our purposes here. It is valuable precisely because it provides reasonable grounds for deciding what sorts of regulation or restriction of human acts should be put in place. In the context of trying to deal with conflicts of interest related to livestock predation, we need to take into consideration all of the human stakeholders (individuals and groups) and ask what kind of policy they would reasonably agree to. In this case, the most significant conflict is likely to arise between those whose interests are best served by preventing predation altogether and those who have an interest in the protection of predators from harm or a hastened death. Typically, on one hand, there are farmers and members of their surrounding communities whose livelihood depends on the livestock industry, and on the other hand, there are animal welfarists, environmentalists, eco-tourists and possibly state environmental agencies tasked with the protection of biodiversity and wildlife. Based on social contract theory, policy makers would need to seek some kind of sufficient consensus, once all stakeholders' interests have been considered.

One way in which this might be achieved is suggested by the authors of a recent article entitled *International consensus principles for ethical wildlife control* (Dubois et al., 2017). They argue that social acceptability is an important principle that should be adhered to by policy makers in these contexts. They point out that, inevitably, human values play an important role. Significantly, different people and communities have very different values from one another. Some place a priority on the protection of property, others on human safety, and others on the protection of biodiversity and the prevention of harm to animals. These values often conflict and may be incompatible (Dubois et al., 2017). In the light of this, these authors recommend the following:

“This diversity of interests calls for an open process of community engagement informed by the relevant science, a transparent approach often overlooked by some government and academic research... An ethical review process with proper governance and resources, similar to that used by animal ethics committees when assessing the acceptability of scientific research involving animals and people, could be a way to include scientific and technical expertise while ensuring community values inform decisions...” (Dubois et al., 2017: 757).

What is clear is that policy makers need to engage in a broad process of consultation with all stakeholders in order to fulfil the social contract.

Our moral obligations to future generations

The human stakeholders who might not come readily to mind are the people of future generations. It is in the nature of many environmental issues that they have implications not just for the current generation, but also for posterity. Extinctions, veld degradation and the loss of ecosystems and wilderness are just some examples of such environmental ethical issues. Since these processes take time, our actions (and inactions) might not deprive those of us living now, but they could lead to a situation in which future generations live in a world far less biodiverse than our own. If, for instance, lethal control

methods were to be applied on a wide scale against predators such as caracals *Caracal caracal* and black-backed jackals *Canis mesomelas*, their numbers could be depleted to the point where the species become endangered. Any subsequent unforeseen serious threat, such as viral disease or persistent severe drought, could be enough to drive these species into extinction. Future generations might well blame the generation that chose to apply a policy of lethal management methods for causing the loss of these predators. But, would they have any right to stand in judgment of previous generations? Does it make any sense to claim that we can have moral obligations to future generations?

This is a question that has led to intense debate. There are theoretical problems with conceiving of moral duties to future people who do not yet exist, whose very existence is contingent, whom we cannot know and who cannot reciprocate any actions we might take in consideration of their interests. Much of the philosophical debate around this issue in the Western tradition has struggled to give an account of how we can have obligations to future people (Partridge, 2003). Yet, there is a pervasive intuition that – at least with respect to the environment – we ought to take the interests of future generations into account, to the extent that this is possible. Kwasi Wiredu writes:

“Of all the duties owed to the ancestors none is more imperious than that of husbanding the resources of the land so as to leave it in good shape for posterity. In this moral scheme the rights of the unborn play such a cardinal role that any traditional African would be nonplussed by the debate in Western philosophy as to the existence of such rights. In upshot there is a two-sided concept of stewardship in the management of the environment involving obligations to both ancestors and descendants which motivates environmental carefulness, all things being equal” (Wiredu 1994:46).

(Note: This reference to duties to ancestors might seem strange to non-Africans. There is a pervasive belief among African communities that the ancestors (the recent dead) continue to influence events in the world. They need to be treated with

respect, lest they inflict some kind of hardship on the living. Wiredu claims that one of the most pressing obligations to the ancestors is the duty to preserve the environment for future generations. For a comprehensive account of this “two sided concept of stewardship”, see Behrens (2012).

This view is supported by many other African theorists such as (Bujo, 1998; Murove, 2004; Nnamani, 2005). John O’Neill is also critical of dominant Western accounts of inter-generational obligation, writing that a:

“... temporal myopia... infects modern society. The question of obligations to future generations is posed in terms of abstract obligations to possible future people who are strangers to us. The argument is premised on the lack of a sense of continuity of the present with both the past and the future” (O’Neill, 1993:47).

He argues that it is important for us to conceive of ourselves as being part of communities that cross generations. Furthermore, the environment is a shared resource, and we share it not only with the current generation, but also with those to come. This imposes on us some obligation to leave the environment in a fit state for the future (O’Neill, 1993, see also Callahan (1981), Weiss (1996) and Partridge (2003) for similar views). These ideas resonate with our day to day intuitions that we ought to be considerate of the needs of those who will inherit the earth from us.

In the context of the livestock predation issue, what this implies is that future generations should also be considered as stakeholders. The interests of future people in still being able to encounter predators outside of captivity need to be taken into account, as do their interests in a generally healthy natural environment, still rich in biodiversity.

OUR MORAL OBLIGATIONS TOWARDS OTHER LIVING ENTITIES AND NATURE

Thus far in this chapter it has been assumed that predators, other animals and plants and the natural environment in general are the kinds of things whose ‘interests’ ought to count when we develop policies about the management of predator impacts on livestock. This assumption entails

that non-human living things have at least some moral standing and that they should be valued in some way. This is obviously not an uncontroversial claim. In fact, historically, there has been a long tradition of believing that only humans have any kind of moral standing, and that, at best, other living beings are merely to be valued instrumentally, in terms of their usefulness to us as humans. This view is known as anthropocentrism, and has historically been a pervasive, dominant view, particularly in the West. Anthropocentrism holds that if we have any moral duties with respect to other animals or natural entities, they cannot be duties to these entities themselves, they must be indirect duties to other human beings. Thus, many of the earliest laws protecting animals protected them on the basis that they were the property of their owners. The enlightenment philosopher Immanuel Kant famously expressed the notion of indirect duties to animals as follows:

“If a man shoots his dog because the animal is no longer capable of service, he does not fail in his duty to the dog, for the dog cannot judge, but his act is inhuman and damages in himself that humanity which it is his duty to show towards mankind. If he is not to stifle his human feelings, he must practice kindness towards animals, for he who is cruel to animals becomes hard also in his dealings with men” (Heath & Schneewind, 1997).

It is very likely the case that many members of the public and policy makers continue to hold anthropocentric views of the moral value of non-humans. By contrast, few ethicists still hold such instrumentalist views today. In the discussion that follows, several non-anthropocentric, non-instrumentalist accounts of the moral value of non-human natural entities are briefly described. The intention is to provide the reader with an overview of the alternatives to anthropocentrism that have been proposed by various theorists. It is acknowledged that a plurality of views exists among the stakeholders whose interests must be taken into account in developing policy regarding livestock-predator management. The discussion that follows should not be understood as advocating for non-anthropocentrism. In developing public policy, a balance needs to be found between competing values and interests. There are

several different non-anthropocentric approaches to animals and nature. They fall into two broad categories: individualist and holist accounts of the moral value of non-human natural entities. These two kinds of accounts will now be discussed in turn.

Individualist accounts: Animal welfarism

If anthropocentrism were right, our only ethical concerns regarding the management of predators would revolve around the competing human interests. However, in more recent times, there has been a growing rejection of anthropocentrism by ethicists and even by members of the public. In the first instance this has been characterised by an increased concern about animal welfare. As we have gradually come to understand that animals are sentient beings that are capable of experiencing pain and pleasure, and prefer comfortable and pleasurable states over unpleasurable ones, more and more people hold the view that animals should not be hurt or harmed without good reason. Going back to the 17th century, we see laws enacted that sought to prevent harm to animals for their own sake. These included laws against pulling wool off sheep and attaching ploughs to the tails of horses. By the 19th century, welfarist concerns started to be extended to animals and some of the first true anti-cruelty laws (protecting horses and cattle) were passed. The first society for the prevention of cruelty to animals was formed in Britain in 1824 (Favre & Tsang, 1993). Since this time the challenge to anthropocentrism by animal welfarists has continued to strengthen.

Individualist accounts: Animals rights/liberation

Towards the end of the 20th century a movement making somewhat more radical claims about our moral obligations towards animals emerged. Known as the animal rights/liberation movement, it went further than the animal welfarists, whose only concern was to prevent cruelty to animals. The historical legacy of the animal rightists has been very significant, and its challenge to our anthropocentric assumptions remains relevant. (Note: In this chapter we only consider the positions of Singer and Regan. Strictly speaking Singer does not use the language of rights about animals, making it somewhat inappropriate to label him as an animal rights theorist.

He might, then, better be called an animal liberationist – even though his views lead to much the same conclusions as those of animal rightists. However, the label ‘animal liberation’ has become associated with radical animal activist groups whose practices are sometimes unlawful and even regarded as a kind of terrorism by some. Singer would likely distance himself from such agendas. For this reason, in the rest of this chapter the label ‘animal rights’ theories is used to refer to the kind of position taken by both Singer and Regan.)

One of the prominent voices of the movement was that of Peter Singer. Appalled by seeing how animals at the time were routinely abused as a result of intensive farming techniques and in experimental research, Singer asserts that we are ‘speciesist’. He sees our behaviour towards other animals as grounded in species chauvinism. He argues that it is clear that many animal species have the capacity to suffer, and that when their suffering is akin to ours, we should take their ‘like suffering’ equally into account as our own. Furthermore, he claims that sentient, self-conscious animals prefer to live than to die. For him this implies that not only should we avoid causing animals to suffer, we also should not ordinarily kill them. He therefore completely rejects meat eating and vivisection (Singer, 1975). This is essentially an account of the animal rights debate of the mid 1970s when these ideas were novel and first came to prominence. Singer’s ideas have developed since then, and what is expressed here are his claims in the 1975 publication cited. It should also be noted that Singer would allow for the killing of an animal if it were the only way to survive.

Singer’s approach is basically utilitarian. Utilitarianism is a moral theory that defines a right action as that which has consequences that maximise the aggregate welfare (utility) of all affected by the action. It follows that the welfare of some affected by the act might be reduced because the purportedly right action is that which leads to the maximum total welfare. On Singer’s account, any beings capable of suffering need to be considered when trying to choose the action with the best overall consequences. In other words, the welfare of all sentient beings must be considered in deciding which actions maximize welfare (Singer, 1975).

Another prominent figure in the animal rights school is Tom Regan. He rejects Singer’s utilitarian grounding for vegetarianism and anti-vivisectionist positions, but

supports similar conclusions. Regan uses deontological, rights-based arguments to defend the basic claim that what is wrong with how we routinely abuse animals is not fundamentally that we cause them pain – what is wrong is that we regard animals as our resources; things we can treat as we like, including causing them suffering and killing them. He argues that the best way to conceive of our moral duties to other humans is in terms of respecting their fundamental rights. Similarly, the best way to understand our obligations to animals is to accord them the same kinds of rights. He argues that there is no justification for not according rights to certain animals. For Regan what counts morally is not the differences between humans and animals, but the similarities (Regan, 1983). He writes that what we share with the kinds of animals we routinely hunt, eat, and use in experiments is that

“We are each of us an experiencing subject of a life; each of us a conscious creature having an individual welfare that has importance to us whatever our usefulness to others. We want and prefer certain things; believe and feel things; recall and expect things. And all these dimensions of our life, including our pleasure and pain, our enjoyment and suffering, our satisfaction and frustration, our continued existence and our untimely death – all make a difference to the quality of our life as lived, as experienced by us as individuals” (Regan, 1983).

For Regan, any being that can be described as an ‘experiencing subject of a life’ in this sense has an inherent value of its own that should be respected. Such beings ought to have basic rights, such as the right not to be deliberately made to suffer, as well as a right to life (Regan, 1983).

The animal rights position has, of course, been challenged. R.G. Frey argues that animals cannot have interests, and only beings with interests can have rights (Frey, 1980). Michael Leahy claims that self-consciousness is necessary for a being to have moral standing, and that self-consciousness requires the ability to use language (Leahy, 1994). These objections are easily refuted, however. There are surely no grounds for claiming that animals do not have interests. They clearly prefer not to be too hot or too cold, to be fed rather than hungry,

and they seek to defend their own lives when they are under threat. There is also no self-evident reason why we should be free to ignore the interests of beings that are not self-conscious or capable of advanced language. Besides, evidence suggests that at least some non-human species are self-conscious enough to be able to recognise their own reflection, and not all humans are capable of language.

A broad consensus against cruelty

The animal rights school has certainly not managed to convince society that animals have rights or that we should all be vegetarians and that all experiments involving animals should be prohibited. But, their challenge to anthropocentric assumptions has been far-reaching. Before the work of the animal rights school, there were theorists who might still have questioned whether there was really any moral wrong in causing animals to suffer. One would be hard pressed to find any serious moral philosopher today who would defend such a view. Interestingly even the theorists, mentioned in the previous paragraph and who argued against the animal rightists, concede that cruelty to animals is morally wrong. Frey, who denies animals have rights, nonetheless claims: “I have allowed that the ‘higher’ animals can suffer unpleasant sensations and so, in respect of the distinction between harm and hurt, can be hurt; and wantonly hurting them, just as wantonly hurting human beings, demands justification, if it is not to be condemned” (Frey, 1980). And Leahy, despite claiming that animals do not have moral standing, argues that “All of this is perfectly compatible with our treating other creatures humanely and with respect and it is a sign of perverted human nature not to do so” (Leahy, 1994). He goes on even to assert that “This must not be seen as condoning the random killing of animals; far from it... our instinctive impulses to avoid cruelty will normally extend to their needlessly being killed” (Leahy, 1994). In upshot, in the post-animal rights era there has been a significant shift towards a general consensus among moral philosophers that cruelty to animals is morally wrong and that killing animals should not only be humane, but that it should be avoided unless there are good counter-weighting moral grounds for such killing. Furthermore, this consensus has found much popular acceptance in many parts of the world. Few would seriously try to defend any notion that animals are mere things that we can treat in any way we like.

What this suggests is that while the animal rights position has not gained that much traction in society at large, animal welfarism has been taken up much more broadly. It is therefore worth considering what an animal welfarist approach to livestock predation would entail. Central to such a view would be that the management of predators should avoid causing suffering to individual animals, as far as possible. In contrast to the animal rightists, welfarists are not necessarily opposed to killing animals, as long as it is done as humanely as possible. This would therefore allow for the use of lethal methods of predator control, so long as they did not cause suffering. Indeed, a painless lethal method would be preferred over a non-lethal method that causes some suffering. Welfarists are also bound to considering the welfare not only of individual predators, but also of prey animals. Thus, there might be an obligation to manage predators in such a way as to minimize the amount of suffering predation causes to livestock. The animal welfarist must in some way seek to weigh up the suffering caused to prey animals against the suffering caused by methods of managing predators. This is clearly a difficult task, and it is likely that welfarists would come to different conclusions. However, it should be noted that a plausible welfarist position might hold that predators should be removed from farming areas, to prevent suffering to prey, and that any methods of management that do not cause suffering to predators – including lethal methods – can be used to achieve this goal.

Individualist accounts: Biocentrism

Both the animal welfarist and animal rights positions are individualist. That is, their focus is on the well-being, interests or 'rights' of individual living beings. Later in this chapter consideration is given to holist, rather than individualist conceptions about our moral obligations to nature. But, before turning to these positions, there is another kind of individualist approach that needs mentioning briefly. The individualist conceptions of our moral obligations towards non-human entities discussed so far only give an account of our moral obligations to sentient beings, mainly animals, birds and possibly some fish. A group of thinkers, often referred to as biocentrists, argue that all living entities ought to be objects of our moral consideration. Paul Taylor asserts that we ought to treat all of nature with respect, because every living

organism has a 'telos' or purpose of its own, and thus has inherent worth (Taylor, 1986). Robin Attfield describes his approach as biocentric consequentialism, which is similar to utilitarianism, defining what is morally right in terms of maximising what is good for all beings worthy of moral consideration. For him what counts is that all organisms are able to thrive (Attfield, 2003). Thus, biocentrists expand the circle of our moral obligations to include non-sentient organisms, too. These positions clearly need some theoretical mechanism for weighing up the competing interests of different kinds of living entities, but it is enough for the purposes of this chapter to highlight that biocentrists do not limit moral considerability to sentient animals only.

Holist accounts: Eco-centrism

This leads us neatly to the next broad position that needs consideration: holism. There are a number of different holist approaches. Some like Deep Ecology and the view based on the so-called 'Gaia hypothesis' make quite radical claims. The focus of this chapter will be on only the more mainstream holist positions, which are often also referred to as eco-centrist. Holists are distinguished from all of the individualist approaches discussed above, by virtue of their claim that our moral obligations extend not just to individual entities, but to groups or 'wholes' too. Thus, holists argue that species, as species (rather than only the individual members of a species) should have a moral standing. So too should ecosystems, natural habitats, and the like. Indeed, the biosphere as a whole is often conceived of as being of direct moral consideration. Grounded in the biological and ecological sciences, holism emphasises the interconnectedness of all organisms in nature, and the importance of recognising that a certain healthy balance is necessary in nature's systems for all things to thrive.

This leads holists to some very different conclusions to those reached by individualists. For instance, holists would give priority to members of highly endangered species, which is something individualist accounts find difficult to do, since they are concerned only with the individual well-being of entities. They would also defend the need to give special protection to species who make a very important ecological contribution. Thus, the preservation of honey bees is vital because of their role in the pollination of important plants, including food crops.

Holists also support the humane culling of members of a species that is threatening the existence of some other more vulnerable species (Palmer, 2003).

The holist position is perhaps best expressed in the words of Aldo Leopold: “A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise” (Leopold, 1949:242). Leopold proposes what he calls a ‘Land Ethic’, arguing that the land (by which he means the environment) is a community which needs to be loved and preserved. His ideas have been taken up and theoretically developed into a more robust environmental ethic by J. Baird Callicott (Callicott, 1986).

Importantly, some of these holist notions find much support in the work of African theorists. While anthropocentric views are no less evident in Africa than in the West, on many African accounts, all beings in nature are regarded as essentially inter-related. Furthermore, humans are not understood as standing apart from nature, but are seen as being integrally part of it. Munyaradzi Felix Murove emphasises the need for “...an ethical outlook that suggests that human well-being is indispensable from our dependence on and interdependence with all that exists, and particularly with the immediate environment on which all humanity depends” (Murove, 2004:195-196). Benezet Bujo claims that “The African is convinced that all things in the cosmos are interconnected. All natural forces depend on each other, so that human beings can live in harmony only *in* and *with* the whole of nature” (Bujo, 1998:22-23). And Godfrey Tangwa claims that “The pre-colonial traditional African metaphysical outlook... impl[ies] recognition and acceptance of interdependence and peaceful coexistence between earth, plants, animals and humans” (Tangwa, 2004:389).

Holists have been accused by individualists of supporting an ethic that is cruelly indifferent to the suffering of individual beings for the sake of the integrity of the whole environment. Some have even called their approach misanthropic: After all, on their view it could be argued that it would be morally justified to cull some humans for the sake of the biotic community. That is not necessarily the case, however, as holists do not disregard the moral requirement to prevent cruelty and suffering of sentient beings. They argue, instead, that we also need to take into consideration the importance of maintaining nature’s balances.

The special value of predators on holist accounts

Some holists, such as Callicott and Holmes Rolston III (Rolston, 1992), have some particularly interesting things to say about predators. Predation, for them, is simply part of nature, and not something inherently bad. Callicott accuses individualist approaches of being fundamentally life-denying (Callicott, 1980), because the simple reality of the food chain (a fundamental basis of life on earth) requires predation for those species that have evolved to be on the higher end of the chain. All living things require nutrition to survive, and some animals survive by consuming others. Both Rolston and Callicott reject the claim, expressed by some individualist animal welfarists (Singer, 1975; Sapontzis, 1987), that we ought to protect prey species from predators and that an ideal world would be one in which predation did not occur. In a sense, to reject predation as an evil is to reject the very evolutionary advances that have made complex life forms (such as humans and other predators) possible. Rolston writes: “A world without blood would be poor, but a world without bloodshed would be poorer too. Among other things, it would be a world without humans – not that humans now cannot be vegetarians but that the evolution of humans would never have taken place” (Rolston, 1992:254). Elsewhere he claims:

“...an Earth with only herbivores and no omnivores or carnivores would be impoverished. The animal skills demanded would be only a fraction of those that have resulted in actual zoology – no horns, no fleet-footed predators or prey, no fine-tuned eyesight and hearing, no quick neural capacity, no advanced brains” (Rolston, 1992:254).

Summarising Rolston’s view, Ned Hettinger writes:

“Evolutionary history is (as Rolston says of animal suffering) “a sad good”... and predation, perhaps especially carnivorous predation, mirrors and drives it. Although dissected and viewed myopically from the perspective of the prey who loses, predation does appear evil, it should be understood holistically as the process of advancement and flourishing of life. For Rolston, the most important

goal of an environmental ethic is to defend the creative, fertile, and sacrificial process of natural history itself. As a result, Rolston must value predation; it is simply natural history writ small" (Hettinger, 1994: 17).

For holists, cats, raptors, canids – the predator species in general – are in some sense special precisely because of the complex evolutionary processes – that have taken many millions of years to unfold – that have made it possible for them to exist at all. This grants them a particular kind of moral status, such that it would be a significant moral wrong for human actions to cause them to become extinct. Rolston asserts that species are akin to blueprints of lifeforms, which we ought to value intrinsically because of their long historical development. Natural history reveals an evolutionary tendency towards the emergence of more complex species whose lives are of higher quality and richness. For Rolston, members of species that are higher on the evolutionary ladder are capable of experiencing far more value richness and are a greater 'achievement' in an evolutionary sense. Thus, predator species have (some) more intrinsic value to Rolston than species below them on the evolutionary ladder (Hettinger, 1994). In addition to this, he argues that there is something about our aesthetic appreciation of these remarkable creatures that adds even more to their moral status. He describes the wolf *Canis lupus* as "one of the most handsome creatures on Earth" (Rolston, 1992:253). He goes on to point out how many people would like wolves reintroduced in areas like the Yellowstone National Park (writing just prior to the wolf re-introduction), how visitors to Africa mostly want to see the big cat species and how the panther *Felis concolor coryi* became the state animal of Florida because children chose this beautiful creature (Rolston, 1992). He concludes: "We admire the muscle and power, the sentience and skills that could only have evolved in predation. Such aesthetic experience is in the eye of the beholder, but the biological achievements are objective in cat and wolf" (Rolston, 1992:253).

Another claim about the special value of predators made by holists relates to their crucial role in ecosystems. The loss of predators can lead to overpopulation of their typical prey species, which can in turn have serious consequences for other species of animals and plants.

Furthermore, Leopold points out that while we should not overstate these claims, predators have a positive impact in terms of improving the health of prey species by weeding out weaker individuals and by controlling rodents, to the benefit of farmers (Leopold, 1949). Rolston argues that even though the individuals who lose their lives to predators experience the ultimate loss

"the species may gain as the population is regulated, as selection for better skills at avoiding predation takes place, and the prey not less than the predator will gain in sentience, mobility, cognitive and perceptual powers. Being eaten is not always a bad thing, even from the perspective of the prey species" (Rolston, 1992:254).

The holist challenge is particularly pertinent when it comes to developing policies for the management of predators, as it highlights the importance of taking ecosystems into account, and explains why species are of value as species. It also grants predators special moral status because of their exceptional evolutionary history and their ecological value.

Hybrid and pragmatic accounts

The accounts of our moral obligation to non-human nature addressed in this chapter thus far are all characterised by taking one particular position and rejecting all of the alternatives. Indeed much of the academic debate in environmental ethics has taken the form of contestation along binary lines: anthropocentrism vs non-anthropocentrism, holism vs individualism, etc. (Light, 2002). While this kind of approach clearly has a place in the academic discourse, it is less helpful with respect to pragmatic decision-making and policy-making in a context of competing stakeholder interests and values. Some environmental ethicists have therefore opted to defend hybrid positions that combine the strengths of erstwhile competing approaches. These hybrid positions are characterised by a concern to find theoretical approaches that are pragmatically useful. Weak anthropocentrists such as Eugene Hargrove (2003) and Bryan Norton (1991) argue that there is no need to reject anthropocentric reasons for ecological protection. They claim that a weak form of anthropocentrism that gives some priority to human

interests without denying the moral value of non-humans is a sound enough basis for an effective ethic of the environment – provided that a long-term view is taken, including the interests of future generations. So-called environmental pragmatists have taken the view that it is counter-productive for environmental ethics to become bogged down in too much theoretical debate, and that it should focus on influencing practice and policy in favour of environmental protection (Light, 2002). Such theorists often embrace theoretical pluralism, affirming what is helpful in all of the possible approaches to value in nature. This pluralist, pragmatic approach is helpful in the context of policy making, as it allows for a variety of views to be recognised and considered. One prominent hybrid approach proposed by Minter & Collins (2005), is particularly relevant to environmental policy makers. They describe it as follows:

“There is a need to bring ethicists, scientists, and biodiversity managers together in a collaborative effort to study and inform the methods of ethical analysis and problem solving in ecological research and biodiversity management. We present a series of cases that illustrate the kinds of ethical questions faced by researchers and biodiversity managers in practice. We argue for the creation of an extensive case database and a pluralistic and integrated ethical framework, one that draws from the theoretical (normative), research, animal, and environmental ethics traditions. These tools form the foundations of a new area of inquiry and practical ethical problem solving, that we call “ecological ethics.” (Minter & Collins, 2005)

MORAL LESSONS FROM THE HISTORY OF PREDATOR MANAGEMENT IN SOUTH AFRICA

The history of the use of various kinds of tactics or methods aimed at reducing predation of livestock in South Africa goes back many centuries. Kraaling was used as a means of protecting livestock from predators by the Nguni peoples from soon after they first inhabited parts of what is now South Africa (Bergman, Bodenchuck & Marlow, 2013). The administration of the Dutch colony at the Cape introduced a bounty system aimed at reducing predation from as early as 1656 (Bergman

et al., 2013). Early European settlers had to deal with a variety of predators including lions *Panthera leo*, spotted *Crocuta crocuta* and brown *Hyaena brunnea* hyaenas, leopards *Panthera pardus*, African wild dogs *Lycaon pictus*, black-backed jackals *Canis mesomelas* and caracal *Caracal caracal*. Indigenous communities would likely have experienced much the same in earlier times. However, after a few centuries of increasing human encroachment, intensive hunting and the use of lethal methods to reduce predator numbers, large predators in South Africa generally became confined to protected areas, specialised wildlife farms and national parks. As a result, since the 19th century it has mainly been black-backed jackals and caracals that have been responsible for predation in farming areas. While other smaller predators might also opportunistically take livestock as prey, the general consensus among scientists and livestock farmers is that it is these two species that are the main concern (Bergman *et al.*, 2013; Du Plessis, 2013). Furthermore, evidence suggests that as a consequence of the confinement of large predators, the lack of competition has increased both the number and the range of black-backed jackals and caracals. This has had an impact on predation on livestock farms and wildlife ranches (Du Plessis, 2013).

Through much of the 19th century, management of predators was mainly focused on extermination of species regarded as a problem in local areas. Lethal methods such as hunting, trapping and poisoning were used. Poisoning clubs were formed, with government support. Kraaling was also used to keep livestock protected. However, over time it became evident that kraaling had negative impacts in terms of increased levels of disease in livestock as well as soil erosion and grazing damage. This led to a shift towards erecting jackal-proof fences, and state subsidies were redirected to this and away from sponsored bounties. Ultimately, fencing proved to have its own disadvantages, especially in terms of limiting the range of smaller wildlife species and threatening biodiversity. Sponsored hunting clubs proliferated in the 20th century (Du Plessis, 2013). More sophisticated traps and more effective poisons began to be employed in the 1960s. These combined efforts created a situation in which the government believed that the predation problem was largely under control by 1967 (Bergman *et al.*, 2013). Nonetheless, a variety of methods, lethal and

non-lethal continued to be employed. This included the introduction of the use of protection collars in the last decade of the century (Du Plessis, 2013). Management during much of this period was characterised by government support in terms of subsidies, incentives and encouragement of management efforts. The use of lethal methods was widespread, and there was little questioning of the ethical appropriateness of such methods (Bergman *et al.*, 2013).

A major shift began to take place from the 1980s. Animal welfarists and animal rights groups became more vociferous and influential. Environmentalism was also a rapidly growing movement across the globe. In South Africa, this had an influence on the political climate, and together with financial constraints, led to government agencies phasing out subsidies for predator management. By the early 1990s government had all but completely ceased to be involved in management programmes (Bergman *et al.*, 2013). After the first democratic elections in South Africa in 1994, priorities changed, and the new Constitution included in its Bill of Rights the right to environmental protection through measures that, among others things, promote conservation and the policy of sustainable development. The concerns of environmentalists now had some support in the Constitution. From the perspective of livestock owners, they were in a sense left to manage predators on their own, and without any official co-ordinated strategy or integrated policy to guide them (Bergman *et al.*, 2013). This is clearly an undesirable situation, as it is mainly left to landowners to manage predation for themselves, with no guarantee that they will take environmental impacts seriously, or not simply fall back on what they know best, the use of lethal methods.

Human responsibility for the conflict

From an ethics perspective there is much that we can learn from this history. In the first place, it is obvious that we, as human beings, bear the responsibility for having created and exacerbated the conflict that exists between us and jackals and caracals, as well as other related threats to the environment. We eliminated the competition from larger predators; we vastly reduced the populations of the natural prey species of predators; we introduced new species of animals in our own interests for meat and wool production; we encroached on the

natural habitats of other species and transformed the land to suit our purposes; we erected the jackal-proof fences that threaten biodiversity; we set the traps and snares and poisoned baits that indiscriminately (and often painfully) killed not only the predators we sought to eradicate, but collaterally, other creatures, too. Ethically, we human actors cannot simply assume that only our interests are relevant in decisions about how to manage the predation problem. We certainly need to give attention to the plight of farmers whose business interests are threatened by predation. But, many would argue that it would be unacceptably anthropocentric for us not to acknowledge a moral responsibility towards predators, to ensure that they are not caused to suffer or die without good cause. Furthermore, we need to consider the effects of our actions on the environment, holistically.

Unintended consequences

Another lesson to be learnt is that actions can have unintended consequences. The complete removal of larger predators from farming areas had the unforeseen effect of increasing the numbers of black-backed jackals and caracals, and consequentially, the predation problem. This in turn, had negative outcomes on biodiversity. Similarly, kraaling might have appeared to be a promising non-lethal method for protecting livestock, but it too had unintended consequences for the health of livestock and the environment. These two examples are enough to demonstrate that it is important to take into account all of the possible consequences of our actions, for them to be ethically justifiable. Furthermore, it is essential that we are cognisant of the concerns of holistic environmental ethicists that it is important to consider these problems holistically, taking into account the implications of our actions for natural systems.

The importance of shifts in public opinion

The history of predator management in South Africa also teaches us the importance of being aware of changes in public awareness and the social acceptability of our actions. There was a fairly rapid and dramatic change in public attitudes to animal welfare and environmental issues in the final decades of the 20th century. Prior to that

time, few would have objected to the use of methods of management that could cause suffering or death. Fewer still would even have been aware of the environmental impact of predator management methods. That has all changed. It is no longer possible to ignore these kinds of concerns. Another pertinent aspect of this shift in public sensibilities is that there is now a new, and often vocal, group of stakeholders whose interests need to be taken into account. Animal welfarists, animal rights advocates, environmentalists, eco-tourists and the many Non-Governmental Organisations and advocacy groups they belong to must now be included in any consultative processes regarding the management of predators. On the grounds of social contract theory, any proposed policies that are devised without the participation of these stakeholders would be ethically unsound. In the South African context, this is supported by law because of the right to a healthy environment that is included in the Constitution.

The role of the state

The history of predator management has another important ethics lesson to teach us: namely, that government has a role to play in assisting the various stakeholders to come to some kind of sufficient consensus on the principles that should guide policy. Leaving the problem entirely in the hands of livestock owners is not going to lead to solutions that have widespread buy-in from all stakeholder groups. It is part of the state's mandate to mediate between conflicting interests and devise policies that will reduce conflicts through participatory processes. Furthermore, while it can be argued that the costs of predator management should be borne by livestock owners and passed on to consumers, there is a case to be made that if the state is to insist on environmental protection and taking public sentiment into account, then the state ought to consider subsidising some of these efforts.

PRINCIPLES FOR THE ETHICAL ANALYSIS OF CURRENT METHODS OF PREDATOR MANAGEMENT

Du Plessis (2013) provides a comprehensive review of management methods currently used in South Africa. He lists the following methods used to manage black-backed jackal and caracal in Table 4.1.

An ethical analysis of the various possible methods could take a number of forms, including a brief discussion of each method in turn. However, since a major aim of this chapter is to provide policy makers with a set of principles that can be used to inform their decision-making, the ethical analysis is structured around some basic principles.

A recent article in *Conservation Biology* represents the outcome of a workshop by a panel of 20 international experts who sought to develop a set of principles for ethical and evidenced-based management of human-wildlife conflicts (Dubois *et al.*, 2017). Since these principles reflect some international consensus, they are informative and should be regarded as having some authoritative weight. The principles identified in the article are expressed under the following headings:

- » Managing human practices
- » Justification for control
- » Clear and achievable outcome-based objectives
- » Animal welfare
- » Social acceptability
- » Systematic planning
- » Decision-making by specifics rather than labels (Dubois *et al.*, 2017).

Table 4.1. Methods used to manage black-backed jackal and caracal. Source: Du Plessis (2013).

Lethal methods	Non-Lethal methods
Coyote getters Denning Foothold traps Hunting Dogs Poison collars Poisoned baits Shooting Snares	Adaptive rangeland and herd management Aversions Box traps Fencing Financial incentives Frightening devices Guarding animals (but see Potgieter, Kerley & Marker's (2016) caveat against the assumption that guard dogs are a non-lethal form of control) Husbandry Protective collars and cellular technology Reproductive interference Supplemental feeding Translocation (Du Plessis, 2013).

Acknowledging human responsibility for human-predator conflicts

As claimed earlier, the primary responsibility for the conflicts that arise in human-predator conflicts lies with ourselves. Ethically, this imposes a duty on us to find the best ways to reduce these conflicts. Given our culpability as humans, Dubois *et al.* (2017:753) assert that the conflicts “should be prevented and mitigated by altering human practices wherever possible and by developing a culture of coexistence”. Essentially they make two recommendations: a change in human practices and a change in culture or attitude.

Regarding the first recommendation, the kind of change in human behaviour envisaged here is a change in actions that create the conflicts in the first place, rather than changes in how we try to manage the conflicts. In the specific case of the kind of predator-human conflict at issue in this scientific assessment, it seems unlikely that there are any changes in human behaviour of the kind that remove the fundamental causes of conflict that would be practicable and achievable at this time. Strong animal rights proponents might well argue that if we all stopped eating meat and phased out commercial animal agriculture completely, there would no longer be any conflict to manage. While this is true, it is clearly not likely that the majority of people would be prepared

to accept such a drastic change in their behaviour. Society's view on this would also be supported by many holist environmental ethicists, who deny that predation is necessarily a bad thing, including human predation of animals. That said, some holists might argue that a significant reduction in the amount of meat humans consume would be good for the environment, and might greatly reduce human-predator conflict. Again, however, it is unlikely that there would be sufficient support for such drastic changes in human behaviour to make such an approach viable. Thus, the recommendation that changes in human practice should be considered as a first option is not obviously applicable to the predation problem in South Africa.

The second recommendation by Dubois *et al.*, (2017) is more promising in terms of its practicability. They suggest that in handling human-predator conflicts it is necessary to develop “a culture of co-existence” (Dubois *et al.*, 2017:753). While it seems that they are concerned with inter-species co-existence, it should be stated that a similar attitude with regards to the relationships between human stakeholders should also be encouraged. Regarding inter-species co-existence, Dubois *et al.* (2017:755) write: “A long-term education-based process, based on preventive action and increased tolerance, is also necessary to move toward a culture of greater coexistence with wildlife”.

Livestock owners are understandably likely to see predators as a threat to their livelihood. From their perspective the interests of predators and of the environment may not generally be given much consideration. Sometimes the threat posed by predators can cause a hardening in attitudes towards them. Farmers can easily begin to see predators as an enemy, and even become vengeful and retaliatory in their behaviour (McManus, Dickman, Gaynor, Smuts & Macdonald, 2014). The historical use of labels such as 'vermin' or 'pests' to describe these creatures betrays an attitude that lays the blame for predation with the predators, without acknowledging our role in creating the problems in the first place. It is this sort of attitude that easily leads to decisions to use lethal methods as a first preference in predator management, without giving due consideration to other possible approaches. One of the responsibilities of the State in this situation may well be to set up programmes to conscientise livestock owners in an attempt encourage a "culture of co-existence". Such a change in attitudes might go some way towards finding solutions that satisfy a large number of stakeholder groups, and avoiding knee-jerk reactions that underlie the desire to eradicate predators rather than co-exist with them.

Effectiveness

One might well ask why the effectiveness of methods of managing predation is presented as an ethical issue. It is obvious why scientists, policy makers and livestock owners would want to know how effective different methods are for pragmatic reasons. Ethicists are no less interested, however, for the simple reason that many management methods have harmful consequences (to predators, other species, the environment, humans and to the bottom line of farmers and possibly even the state). Whenever our actions cause harm to others, we have related ethical obligations. Often it is incumbent upon us to weigh up competing harms, so as to be able to justify our actions. This is based on consequentialist thinking about morality, and is intuitively quite plausible in situations such as this. Thus it might be possible to justify some very minor harms to predators – say, in terms of using methods that might sometimes cause them to suffer a little – if the methods used were exceptionally successful in reducing predation. On the other hand, we

could not justify serious harms to predators if using a particular method has little or no effect on preventing predation.

While shooting problem species remains a popular management choice in South Africa, it is not at all clear how effective it is in reducing predator numbers over the long term. It may fail to remove problem individuals; when individuals are removed from an area, others may simply take their place; and there is some evidence that younger individuals are more likely to be shot than older, habituated individuals (Du Plessis, 2013). Since the harmful consequences of shooting are obviously not trivial, it would not be ethical to resort to shooting as a first-line approach to predator management without evidence that it is very effective.

Similar concerns arise with regard to most of the lethal methods of management that can be used. In each case, the amount of harm done needs to be weighed up against the benefit. If levels of effectiveness are low, it may well be that the harms cannot be morally justified. Denning – the practice of removing or killing young from their dens – is harmful not just to the young – its ecological impact is uncertain. The practice is also likely to be deeply offensive to animal welfarists. Foothold traps, snares, coyote getters, poisoned baits, poison collars and hunting with dogs all have potentially harmful consequences. In the first place, they can cause suffering and death to targeted predators. Furthermore, while some of these methods are more selective than others, they can all potentially cause the same kinds of harm to other species – potentially even humans. They may also have other harmful effects on the environment (Du Plessis, 2013). Again, these are serious harms, and these methods would not be morally justifiable unless they were effective.

Some non-lethal methods are potentially harmful in a number of ways. Using dogs as guarding animals has shown some potential in effectively reducing predation (McManus *et al.*, 2014). However, some studies done in local conditions suggest that the method may not always be as non-lethal as it seems, as some individual dogs have been shown to kill target predator species, other species and even some livestock. Furthermore, where they don't kill other animals they might cause injury and trauma. While there may be ways, such as better selection of dogs and better training, that could reduce

these harms (Potgieter *et al.*, 2016), the potential for such harm cannot be ignored. Again, some relatively small harms might be justifiable, but only if the method is, in fact, effective. Fencing has potentially harmful environmental impacts, but might yet be shown to be a fairly effective method (Heard & Stephenson, 1987). It is an expensive option, in terms of initial outlay, and as such may be harmful to the business interests of farmers.

Another non-lethal management method that might cause harm is the use of conditioning taste aversion. It entails treating baits (usually carcasses of livestock) with chemicals, so that when predators eat the bait they become nauseous. It is not known what other harms the chemicals used may cause to the targeted species or other creatures that might scavenge on the bait. Many studies have found the method to be largely ineffective, which would make it hard to justify ethically (Du Plessis, 2013). Husbandry practices such as kraaling livestock during lambing season or at night may lead to potential harms in terms of increased incidence of disease and to poor grazing conditions. The effectiveness of these methods is very important ethically. Should they be shown to be extremely effective, some minimal harms might be justifiable. But causing harm for no benefit is not. Furthermore, it is not fair to expect farmers to bear the costs of these interventions if they are not likely to be successful.

The need for evidence

In trying to decide what is the most morally right action out of a number of possibilities, we need to have information that enables us to understand causes and effects, impacts, costs, threats, responsibilities, and the like. For instance, it is difficult to predict the possible effectiveness of a predator management method without knowing about the feeding behaviours of the specific predators. If it is true that caracals are more likely to target livestock when they are nursing young, then denning combined with translocation might be an effective and humane method. What is important is that there is not only a scientific obligation for conclusions to be evidence-based, there is also an ethical obligation to ensure that our decisions are based on as much sound evidence as possible (Dubois *et al.*, 2017).

This is why a scientific assessment of this nature is ethically so important. Bringing together the best

evidence from as many sources as possible, taking into account the many different kinds of data that are available, goes a long way to increasing confidence in any conclusions that are drawn. Where there is sufficient evidence, it may also be possible to convince certain stakeholders to reconsider entrenched views, making consensus on some items more likely.

Unfortunately, it is often the case that there is a paucity of appropriate evidence-based studies. The literature on the conflict between predators and livestock in South Africa is characterised by repeated claims that no or little research has been done, in local conditions, to answer critically important questions (Bergman *et al.*, 2013; Du Plessis, 2013). Clearly, it is not possible for research to be undertaken that will fill all of the gaps in our knowledge. However, a comprehensive assessment such as this might at least identify the most critical and urgent research that should be undertaken. For instance, in his comprehensive account of management methods employed in South Africa, Du Plessis (2013) notes, as he discusses each method in turn, that there are either no or very few local studies on the effectiveness of almost all of these methods. That does not entail that we ought to engage in research on all of these methods, however. For instance, he points out that a majority of international studies on conditioning taste aversion (CTA) find it to be ineffective (Du Plessis, 2013). It is possible that since the South African predators concerned and conditions are different from those in the international studies, it might turn out that CTA is effective here. But, the evidence we do have suggests that there might be other more promising methods that are worth investigating first. There might also be methods, the effectiveness of which is largely unknown, but that can be ruled out because it is known that the costs involved are completely prohibitive. If resources are to be expended on research, this needs to be morally justified on the basis that such research is promising and likely to produce results. Wastefulness and engaging in research that is unlikely to provide useful results is ethically questionable.

Certain kinds of studies investigating gaps in our knowledge might also be identified as unnecessary or undesirable by virtue of their social unacceptability. For instance, if there is widespread disapproval of methods such as traps and snares, because they are seen as cruel and non-selective, it might not make sense to study

their effectiveness or investigate their relative cost-effectiveness. After all, some would be opposed to the studies themselves, on ethical grounds. And there is not much point in obtaining more knowledge about methods that we already know are unlikely ever to be implementable.

Animal welfare

The importance of giving consideration to animal welfare has already been addressed substantially in this chapter. However, there are a few other important ethical principles to be considered when assessing the relative moral justifiability of various management methods.

The first is that the more harmful a practice is to welfare of animals the more of a burden there is on us to provide good reasons that can justify the practice. While it is a matter of some debate whether death is the most serious harm that can befall conscious beings, there is no doubt that for such beings it is a non-trivial harm. It may be argued that causing the loss of animal lives can be morally justified on the grounds that this results in significant benefits for humans (indeed a lot of research using animals is justified in this way). But, no serious ethicist would defend the morality of killing animals without good reason. With this in mind, from an ethical perspective, non-lethal methods of management are normally going to be more easily justified than lethal methods.

Methods that cause suffering and distress are also problematic, ethically. Again, they place an enormous burden on us to show that they are necessary, and that other methods cannot achieve the same or similar results. While killing a predator with a clean shot from a hunting rifle might not cause it much suffering, a botched shot could. Animals that are poisoned or caught in foothold traps or snares may experience prolonged suffering. Such methods will require a great deal more justification than many of the other options available.

Dubois *et al.* (2017:756) sum up the consensus view on animal welfare of their international group of experts as follows: “Control methods should predictably and effectively cause the least animal welfare harms to the least number of animals”.

Selectivity

Management methods (and particularly lethal methods) differ significantly in terms of how species-selective they are (Du Plessis, 2013; Potgieter *et al.*, 2016). Traps, snares, coyote getters and the use of poisoned baits are generally non-selective, and many kinds of non-target species may be killed or injured by these devices. Guard dogs might also sometimes kill or injure other species. CTA is also not very species-selective, and could cause harm to animals others than the species targeted.

The more non-species-selective a method that causes harm is, the more difficult it is to justify ethically. While it may be possible to argue that the harms caused to some predators can be justified because they are outweighed by benefits to the livestock industry, this argument is not as sound when used to justify the suffering and death of species that are not responsible for the predation problem.

Environmental impacts

We cannot claim that any method of managing predators is ethically justified without giving due consideration to the possible environmental impact of such a method. This has already been argued for earlier in the chapter and will only be dealt with briefly here. This principle applies to both lethal and non-lethal methods. There are some methods, the environmental impact of which may be of such significance that it should be a key factor that needs consideration. These include: traps, snare, poisons, denning, fencing, translocation, aversion techniques, sterilization and kraaling.

Social acceptability

It has become more and more obvious over the last few decades that policy makers have to give due consideration to the social acceptability of initiatives. Furthermore, public opinions and mores can change quite rapidly at times, which also needs to be considered. Dubois *et al.* (2017:756) write:

“Decisions to control wildlife should be informed by the range of community values alongside scientific, technical, and practical information. Decisions on whether and how to control wildlife usually involve balancing benefits and harms.

Scientific and technical information can inform decision making.... Nonetheless, decisions regarding wildlife control inevitably involve human values which differ from person to person and across communities”.

It has already been pointed out that in terms of social contract theory, we have a moral obligation to formulate policies that most rational agents would agree to. What this entails for issues such as livestock-predator conflict is that it is important that all stakeholders are included in consultative processes and feel that they have been heard. This approach has been adopted as a basic principle for how this scientific assessment has been conducted.

In terms of predator management methods, public opinion has swung in favour of preferring non-lethal and humane methods. The authors of one review article write: “Ethical decisions should consider the value of society at large and the intrinsic value of all of the individual animals involved... For instance, two large scale studies in the US suggested lower public acceptance of lethal methods than of non-lethal methods and that humaneness was important to the public” (Treves, Krofel, McManus, 2016: 386). Similarly, in a study on the use of guarding dogs in Namibia, Potgieter *et al.* (2016:514) write:

“Large-scale lethal control using indiscriminate methods such as poisoning, snaring and hunting can be environmentally damaging and are increasingly socially unacceptable”. This general trend with respect to public opinion is one that policy makers need to give appropriate attention to.

Cost-effectiveness

The cost-effectiveness of each method of management is clearly of pragmatic importance. As long as livestock farmers in South Africa continue to shoulder the financial burden of management themselves, cost-effectiveness will understandably be an especially weighty consideration for them. Ethically, since livestock owners are key stakeholders, their interests must carry significant weight. They also play an important role in food production and contribute to the economy through providing employment and in other ways. Furthermore,

the consumers of their meat products also have an interest in the affordability of these products. The methods that are best for animal welfare, most socially acceptable and environmentally sound might turn out to be relatively expensive. This would lead to a conflict of interests between animal welfarist and environmentalist groups on the one hand and farmers, their employees and consumers on the other. In such an eventuality, it may be that the state would need to consider ways of subsidising management again, as an incentive to get farmers to adopt non-lethal, more humane, and ecologically sound management methods. This would entail that taxpayers would become a much more interested stakeholder group, whose concerns would need to be considered. Creative approaches to raising funds for subsidies (for instance, a tax on eco-tourists) might be more palatable to taxpayers than simply adding a further strain on the fiscus.

Responsibility of the state

This brings us back to the responsibility of the state in managing the conflict between livestock owners and predators. The current situation in South Africa, where the responsibility for managing predators largely falls on the shoulders of individual livestock owners, and in which there is no co-ordinated approach and a lack of clarity on policy, needs to be addressed. It is the responsibility of government to mediate between competing interests and to facilitate the formulation of clear, workable policy and even legislative reform, where necessary. In a constitutional state, there is an obligation to ensure that all stakeholders’ interests are considered and that solutions are found that are fundamentally fair. The methods of predator management that are most suitable in terms of the social contract may not be practicable without the participation and intervention of the state and the use of some state resources.

CONCLUSION

The conflict between predators and livestock owners gives rise to many ethical issues. It is a very complex situation in which there are many different stakeholders who have competing interests. Finding a way to accommodate and balance the interests of all parties is hardly simple. This chapter has tried to give an account of the many ethical

issues that need to be considered, as well as to introduce some theoretical tools that applied ethics can provide to assist in navigating through complex ethical questions. It has also proposed, explained and applied a number of principles for the ethical analysis of current methods of predator management that ought to inform the process of policy making.

Box 4.1 Against the use of lethal predator control

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Here I examine the kinds of considerations that need to be brought to bear on the ethics of lethal methods of predator control in reducing livestock predation. I will examine by way of a cost-benefit type of analysis whether lethal methods of predator control are ethically justifiable. I assume here that animals have moral status which do not necessarily amount to moral rights. Debates in animal ethics are often artificially positioned as disagreements between those who do and those who do not hold the view that animals are the bearers of moral rights. This usually results in a stalemate, as neither side can find common agreement. However, the claim that animals have moral status is a necessary condition if discussions on the ethics of lethal methods of predator control are to have any traction, since ethical issues arise only if one can talk meaningfully of a being's moral interests. The cruel nature of some lethal methods, such as gin traps for example are taken - even by proponents of their use - as relevant considerations to their continued use. Such considerations make sense only in the context of animal welfare, which presupposes that animals have interests. Such interests, I argue, lie at the heart of the claim that animals have moral status. I thus take it for granted for the sake of this discussion that animals have moral status, but I do not claim that this status necessarily amounts to the possession of moral rights. Were non-human animals to be accorded moral rights, lethal and harmful methods of predator control would be impermissible, except perhaps in extreme circumstances. Given the context in which discussions of predator management occur, and given the current moral status of animals in society, I am assuming for the sake of the argument that animals do not have moral rights. However, I argue that their possession of moral status nevertheless places severe constraints on how they may be treated. This position is also consistent with the ways in which ethical decisions involving animals' interests are deliberated - namely, via appeal to a utilitarian "cost-benefit" analysis, which is standardly employed in animal research and elsewhere. Animal ethics committees, for example, decide whether a research protocol involving the use of animals is morally justifiable by weighing up the harms done to the animals against the purported benefits of the experiment. Such a utilitarian calculation thus assumes that animals have moral status. I would like to adopt a similar sort of strategy in the discussion that follows by asking whether - and if so under what conditions - lethal methods of predator management are ethically justifiable. I shall restrict my analysis to the question regarding whether - and if so, under what conditions - the lethal management of predator control is morally justifiable given the *status quo*. The broader ethical issues regarding animal agriculture are being set aside for the sake of the argument, but they would nevertheless be relevant in a more global appraisal.

Lethal methods of predator control clearly inflict enormous harms on individual animals, which suffer from being hunted, trapped, or killed by other means. Many lethal methods such as gin traps are not only extremely cruel but trap and kill indiscriminately. The negative impact of killing predators on biodiversity is enormous: most large carnivores are in decline globally and "conflict with local people,

particularly over depredation on livestock, is a major cause of this decline" (Ogada, Woodroffe, Oguge & Frank, 2003). In North America, wolves "were deliberately exterminated in the lower 48 United States, except in northeastern Minnesota, primarily because of depredations on livestock" (Bangs & Shivik, 2001:2). In South Africa, the Oranjejag hunting club in the Free State between 1959 and 1991 killed 24 589 jackals and 3 377 caracal, as well as other non-predatory species including over 65 000 Cape foxes *Vulpes chama* (Bothma, 2012). Lethal controls have also led to the extinction of several species, such as the Tasmanian tiger *Thylacinus cynocephalus* and the Falkland Island wolf *Dusicyon australis* (Woodroffe, Thirgood & Rabanowitz, 2005). Furthermore, eradication of a target species may have unpredictable knock-on effects: "Reducing the density of top predators may cascade through ecosystems with mesopredators increasing in density, which can have unpredictable consequences for prey populations, conflict rates and the services ecosystems provide to humans." (Treves & Naughton-Treves, 2005:91) Thus from both an animal welfare and a conservation perspective, finding ways to replace lethal with non-lethal methods of livestock protection is a moral imperative. This is especially so since there is evidence to suggest that predators - at least in certain instances - are not the major cause of livestock losses. For instance, Bangs & Shivik (2001:2) claim that natural mortality was the leading cause of calf death in the Northwestern US; wolf predation "was the second leading cause of death", at 29% of calf loss. They also argue that, even where wolves live near livestock, "conflicts were uncommon considering the potential for depredations" Bangs & Shivik (2001:3). Research by Roberts (1986:150) concludes that domestic dogs and not predators were the major cause of sheep killings on farms in KwaZulu Natal in the early 1980s: "Of 395 sheep carcasses examined, predation was attributed to black-backed jackal in 50 instances, caracals in 9, and domestic dogs in 350". In his 2012 report, Bothma (2012:6) notes that "in a sheep production region in KwaZulu-Natal black-backed jackals have been estimated to be responsible for the loss of 0.05% of the sheep population". If predation does not count as the main or even a major cause of at least some livestock losses, then blaming wildlife is aiming at the wrong target.

In addition to the ethical concerns regarding the harm caused by killing predators, in terms both of animal welfare and loss of biodiversity, there are also scientific concerns - short of total eradication (which would obviously be completely unjustifiable) - that lethal methods are ineffective. Bothma (2012:7) notes that "to date all attempts at the control of black-backed jackal populations have failed" he further notes that "the black-backed jackal and caracal are the products of a long period of development and co-existence with humans and are adapted to it. It is impossible to control their population sizes except through regional or national extermination" (Bothma, 2012:14). The scientific arguments against lethal methods are also referred to by Natrass and Conradie, who claim that "the science of predator ecology" shows that "predator numbers can increase as a result of persecution" (Natrass & Conradie, 2015). If so, then killing predators would be unjustifiable given the paucity of benefits that would accrue to farmers when weighed against the enormous resultant harms.

Thus the ethical arguments against the use of lethal methods seems strong: the harms caused by predators outweighed by disproportional killing or culling, especially when the methods used are indiscriminate and affect either non-target species or members of target species that are not responsible for livestock predation. In addition, the science seems to indicate that lethal methods are not effective. Thus the replacement of lethal with non-lethal methods of either predator control or livestock protection seems both logical and ethically mandated. Indeed, even if the science were wrong and lethal methods were effective in limiting predation, this would not remove the moral imperative to find non-lethal methods. This is so because a cost-benefit analysis must look not only at the *actual* harms or benefits

that result from a particular practice, but it must also take into account whether reasonable alternatives would result in *lesser* harms. (This is the case where animals are used for medical research: even if a protocol would be morally justifiable on the grounds that its outcomes would result in greater good than harm caused, it may still be rejected by an ethics committee if reasonable non-animal alternatives were available.)

If they would, then such alternatives should be implemented instead, providing of course that non-lethal methods do not cause other serious harms to predators. McManus *et al.* (2014) argue that tools for protecting livestock from predation “should benefit both farmers and wildlife conservation” and should include the following: “persistent efficacy, minimal unintended environmental consequences, selectivity towards problematic individuals, lower cost than that of the depredation prevented, and social acceptability” (McManus *et al.*, 2014). Non-lethal methods seem to tick most, if not all, these boxes. Non-lethal methods should also not result in the suffering of targeted individuals, even if such suffering does not result in death. McManus *et al.* (2014) also argue that in addition non-lethal methods are not only more efficacious than lethal methods but are also cost-effective to the farmer. Their research into the relative advantages of non-lethal vs lethal methods was conducted over a three year period on 11 commercial livestock farms in the Eastern Cape. Farmers used a variety of non-lethal methods, which included alpacas, dogs and collars. During the 1st year of research, the costs per head of non-lethal control resulted in an increase in savings to the farmer when compared with lethal control use. There was also a mean decline in depredation.

“Our findings suggest that non-lethal mitigation can effectively reduce depredation and the economic costs of carnivores in the vicinity of livestock farming. Farmers saved 55.1% and 74.6% during the first and second years of non-lethal control, respectively, compared to expected losses during lethal control. Even where lethal controls were cheaper to implement than non-lethal methods, the lower-than-expected depredation resulted in savings in both years when non-lethal controls were used. There was a mean saving of USD 13.79 per head of stock in the first year of non-lethal control and USD 17.41 per head in the second, compared to what would be expected when using lethal control only. Overall, farmers saved a mean of USD 20,000 during the first year of switching to non-lethal measures, which was equivalent to the value of 138 livestock. Initiating and operating non-lethal control during the first year was cheaper than continuing lethal control on the majority of study farms, and depredation rates were invariably lower. In short, non-lethal measures were cheaper than lethal control on 91% of the farms in the first year of implementation” (McManus *et al.*, 2014:692).

Another study by Potgieter *et al.*, (2015), found that the use of Anatolian guard dogs resulted in fewer losses to predation, which resulted in fewer killings of cheetahs by farmers. However, they also discovered that the guard dogs themselves were responsible for killing predators, including non-target species, and argue that “corrective training for dogs that chase or kill non-target species should be implemented” (Potgieter *et al.*, 2015:514) in order to prevent this. It should be noted that there are many methods of non-lethal predator control, and it may be that some methods work better than others, depending on the region, the nature of the livestock farming and the kinds of predators involved. Shivik (2004:64) outlines a variety of non-lethal methods and notes that “many methods that are applicable in small pasture situations ... may have little or no applicability in large, open-range situations” and

stresses the need “to categorize and understand the plethora of methods that are being advertised by both scientists and charlatans”. However, given the obvious need to develop effective non-lethal methods, the ‘field and body of knowledge on non-lethal techniques is growing’ (Shivik, 2004).

Given the obvious advantage of non-lethal over lethal methods from a variety of perspectives - animal ethics, conservation, livestock protection, financial costs and social acceptability - the case for non-lethal methods seems strong. Certainly the *moral* argument is extremely strong. If this is the case, then the converse - namely that lethal methods are morally acceptable - is unsupported. If this is so, then, at the very least, conservation authorities should be extremely reluctant to permit lethal methods, especially given the evidence that lethal methods implemented by farmers have not succeeded in lowering predation. Further research into different kinds of non-lethal methods is also required to find the best methods for different farming situations. However, the clear harms of lethal methods of predator control provide a *prima facie* argument against their use, certainly as a default method, and the burden of proof should thus fall on those who wish to defend their continued use rather than on those who oppose them. For this reason, authorities should, as far as possible, mandate against their use while simultaneously provide incentives for the use and development of non-lethal methods. Pragmatically, farmers will be persuaded to give up traditional methods only if alternative methods are available, effective and cost-effective.

Box 4.2 Knowledge gaps

An ethical analysis of the management of livestock predator impacts in South Africa is dependent on empirical evidence. There are significant gaps in our knowledge regarding the effectiveness, cost-effectiveness, selectivity and social acceptability of the various predation management options at our disposal. What is especially lacking are studies done in the local context.

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LEGAL CONSIDERATIONS IN THE MANAGEMENT OF PREDATION ON LIVESTOCK

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INTRODUCTION

Losses to livestock caused by predators affects both commercial farmers carrying large numbers of livestock as well as small-scale and subsistence livestock farmers on communal land and can pose a significant challenge to the economic survival of many new and emerging farmers or could ultimately result in fewer people choosing to farm with livestock (Grobler, 2016). This chapter outlines the rights of landowners to eliminate or control predators that cause damage to livestock on communal land or privately-owned land. The predators concerned could occur naturally on the land or they could have moved from neighbouring land that is either privately-owned land, communal land or state land and which may or may not be declared a protected area.

THERE is no clear legal framework for the management and control of predators in South Africa. Although there is a plethora of national and provincial legislation and policies, much of this is conflicting and outdated. The provincial nature conservation ordinances that applied in pre-1994 South Africa to the four provinces of the Cape, Orange Free State, Transvaal and Natal, still apply in some of the nine new provinces. In addition, some of the nature conservation ordinances of the former homelands continue to apply in some areas. To make matters more confusing, the legislation varies between provinces.

The provincial nature conservation ordinances that were in place and operational well before the advent of the “new” South Africa in 1994 should also be seen against the backdrop of post-1994 environmental

legislation. Post-1994 has seen the enactment of national environmental legislation and the introduction a number of statutes of dealing with environmental issues e.g. the enactment of the framework National Environmental Management Act 107 of 1998 (NEMA): the National Environmental Management: Biodiversity Act 10 of 2004 (Biodiversity Act) and the National Environmental Management: Protected Areas Act 57 of 2003 (Protected Areas Act).

In an attempt to address the problems caused by predation on livestock and game, draft Norms and Standards for the Management of Damage-causing Animals in South Africa (Anon. 2016) were published under the Biodiversity Act. However, because of the administratively burdensome procedures contained within these draft Norms and Standards, it is unlikely

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that they will be of much practical assistance to livestock farmers if finalised as currently framed. The outdated and conflicting legislation and overlapping administration of laws has exacerbated the frustration of livestock farmers confronted by livestock predation. This has resulted in livestock farmers in some instances taking matters into their own hands in an effort to minimise losses to their livestock.

The origins of nature conservation legislation can be traced back to the arrival of the colonial settlers at the Cape in the seventeenth century. In Jan Van Riebeeck's journal entry for 30 March 1654, he complained of steady losses of sheep: "many are carried away and devoured every day by leopards, lions and jackal (Skead, 2011). Five laws were promulgated within five years of Van Riebeeck's arrival, to protect gardens, lands and trees from destruction by wildlife (Rabie & Fuggle, 1992). The predecessors of today's provincial nature conservation ordinances have their roots in the respective ordinances which were promulgated shortly after the creation of the Union of South Africa in 1910, when nature conservation was a matter of provincial competence within the four provincial nature conservation departments. The current South African Constitution (The Constitution of the Republic of South Africa, 1996 - cited hereafter as the Constitution) adopts this historical status quo by designating "nature conservation" to be a matter of concurrent national and provincial competence.

Historically, the concept of nature conservation was construed narrowly as the setting aside of protected areas and the conservation of indigenous wild animals, plants and freshwater fish, and which was regulated by provincial nature conservation ordinances (Rumsey, 1992). Today, however, it is acknowledged that nature conservation includes concerns such as the conservation of biodiversity; the maintenance of life-support systems; and the sustainable use of species and ecosystems, be it consumptive or non-consumptive. Related to this trend is the modern emphasis on making conservation pay; a reaction to the decreasing capacity of the state to subsidise the cost of managing protected areas. Legal and managerial mechanisms are being developed to preserve our wildlife heritage while simultaneously ensuring that it generates income, either directly (through harvesting) or indirectly (through tourism), particularly in the context of the need to redress the

imbalances of South Africa's past. This is reflected in the establishment of a number of provincial statutory boards to manage wildlife resources in a more efficient financial manner in their respective provincial government counterparts. In addition, while nature conservation laws have been embedded in the statute book since 1910, the last two or three decades have seen the growth of a body of laws around what can broadly be described as "environmental management".

Although animal anti-cruelty legislation has been enacted (Animals Protection Act (71 of 1962); Performing Animals Protection Act (24 of 1935); and Societies for the Prevention of Cruelty to Animals Act (169 of 1993) this is primarily in regard to the treatment of domestic animals. There is now increasing pressure for the ethical treatment of both domestic and wild animals, raising interesting constitutional questions pertaining to animal rights (see also Chapter 4).

With the adoption of a new Constitution in 1996, the four provinces became nine, and the former homelands, which had their own individual nature conservation laws, were simultaneously re-incorporated into South Africa. As a result, each of the nine provinces now has (at least in theory) its own individual nature conservation law which subsumes any previous homeland legislation in its area and which governs nature conservation in that entire province. But, as detailed below, some provinces have not yet adopted their own new nature conservation laws and continue to apply the respective old nature conservation ordinances as well as, in some provinces nature conservation law of the respective former homelands. Some of the new provinces, for example Mpumalanga and the Northern Cape, have put in place new, consolidated nature conservation laws. Some provinces have developed, or are in the process of developing, provincial environmental management laws, while other provinces, still apply the nature conservation laws which applied in their respective areas prior to the advent of the new South Africa.

A further complication is that since "environment", like "nature conservation", is now a matter of concurrent national and provincial competence, many of the previous nature conservation authorities have now also been encumbered with administering national environmental management laws without their having the capacity or expertise to do so.

LEGISLATIVE FRAMEWORK

The regulation of wild animals in South Africa has three concurrent sources: international treaties and agreements, national legislation and provincial legislation.

The international dimension

International wildlife agencies

The primary international inter-governmental agencies dealing with international aspects of wildlife, are the United Nations Environment Programme (the UNEP) and the UN Commission on Sustainable Development (the CSD), which are responsible for the formulation of the Principles for Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forest (UNCED Forest Principles) and Agenda 21. The Food and Agriculture Organisation of the United Nations (the FAO) is involved in the international aspects of forestry and plants, while the UNEP is responsible for the adoption of many of the wildlife conventions discussed in that chapter, to which South Africa is a party (Dugard, 1994).

The most important international non-governmental organisation is the International Union for Conservation of Nature (IUCN), formerly known as the World Conservation Union. It includes both governmental and non-governmental members, and plays an active and important role in developing treaties to protect wildlife and for the conservation of natural resources. In 1980 the IUCN pioneered the 1980 World Conservation Strategy, along with the World Wide Fund for Nature (the WWF) and the UNEP, and hosted the World Parks Congress in Durban in 2003. It has prepared the preliminary texts for a number of conventions which have been developed at later negotiations; for example, the UN Convention on Biological Diversity (CBD). There are also NGOs such as Greenpeace, Friends of the Earth and WWF which lobby governments to make changes to environmental legislation.

Important wildlife conventions which South Africa has adopted include the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) and the CBD. South Africa is required to enforce the provisions of these conventions, some of which provide an additional

measure of protection for those animals classified as problem or damage-causing animals.

The Southern African Development Community

The Southern African Development Community (SADC) Treaty, a regional economic co-operation agreement was entered into in 1992.

The Protocol on Wildlife Conservation and Law Enforcement of the Southern African Development Community aims to establish, within the framework of the respective national laws of each State Party, common approaches to the conservation and sustainable use of wildlife resources and to assist with the effective enforcement of laws governing those resources.

The Protocol applies to the conservation and sustainable use of wildlife, excluding forestry and fishery resources. Each State Party has to ensure the conservation and sustainable use of wildlife resources under its jurisdiction, and that activities within its jurisdiction or control do not cause damage to the wildlife resources of other states or in areas beyond the limits of national jurisdiction.

In line with article 4 of the Protocol, appropriate policy, administrative and legal measures have to be taken to ensure the conservation and sustainable use of wildlife and to enforce national legislation pertaining to wildlife effectively. Co-operation among member states is envisaged to manage shared wildlife resources as well as any trans-frontier effects of activities within their jurisdiction or control.

The Protocol establishes the Wildlife Sector Technical Co-ordinating Unit; the Committee of Ministers responsible for Food, Agriculture and Natural Resources; the Committee of Senior Officials and the Technical Committee. The Wildlife Conservation Fund is established by article 11.

The constitutional dimension

Wildlife rights

Although South Africa has one of the most liberal constitutions in the world, as well as a progressive Bill of Rights, the Constitution does not go so far as to extend rights to animals. Animal rights groups nevertheless campaigned vociferously for the inclusion of animal

rights during the negotiating process for the Bill of Rights chapter in the Constitution. Rather than including animal rights, these demands could have been accommodated to some extent by incorporating a duty on people to treat animals humanely.

These ethical concerns have manifested both internationally and locally in concern for the humane treatment, prevention of cruelty and the unnecessary killing of animals. Examples include the parliamentary opposition to fox-hunting in England and the vociferous local public outcry against the inhumane treatment of the Tuli elephants (Anon., 1999). The relevant South African legislation, namely the Animals Protection Act 71 of 1962; the Performing Animals Protection Act 24 of 1935; and the Societies for the Prevention of Cruelty to Animals Act 169 of 1993, was developed primarily as a result of the concern for domestic rather than wild animals, covering (for example) the treatment of dogs, but also includes wild animals within its ambit.

The Bill of Rights and constitutional presumptions

It is relevant to consider the possible impact of constitutional presumptions on criminal and civil legal proceedings for wildlife predation with respect to the presumption of negligence. In *Prinsloo v Van der Linde and Another* (BCLR, 1997), concerning section 84 of the now repealed Forest Act 122 of 1984, an action was instituted for damages allegedly caused by the spread of a fire from the neighbouring applicant's land. The land in question was situated outside a fire control area and the case centred on the constitutionality of a provision of the repealed Forest Act, or the common law, which presumed negligence unless the contrary was proved.

The Court found that the provisions of this section were not inconsistent with the Interim Constitution (The Interim Constitution of the Republic of South Africa Act 200 of 1993; hereafter the Interim Constitution) and remitted the matter to the lower court to be dealt with. It should also be noted that the Interim Constitution (see Section 34(2)) specifically provided that the presumption of negligence does not exempt the plaintiff from the onus of proving that any act or omission by the defendant was wrongful.

The Constitution and the administration of nature conservation

Nature conservation has historically fallen under the purview of the provinces. The Constitution respects this historical position by stipulating that "...nature conservation excluding national parks, national botanical gardens and marine resources" is a matter of concurrent national and provincial competence (Sch 4 of the Constitution). However "environment" is similarly a matter of concurrent national and provincial competence (Sch 4 of The Constitution).

The classification of wild animals (including predators) that are not privately owned as *res nullius* (owned by no-one), may be inconsistent with section 24(b) of the Constitution, as they form part of the environment that must be protected for the benefit of present and future generations. As trustee of the environment for future generations, the State is obliged to conserve wild animals that are part of the public estate, and more specifically, in terms Section 17(c) read with Section 3(a) of the Protected Areas Act, is obliged to conserve all wild animals occurring in protected areas. Namibia expunged the *res nullius* category from its wildlife law by adopting Article 99 of its Constitution which states that all natural resources belong to the State unless otherwise owned by law. A similar approach may be appropriate for South Africa and if adopted would make it easier for livestock farmers to institute claims against the State for damage caused to livestock by wild animals. This would however require an amendment to the constitution which is a significant obstacle.

The common law

The acquisition of ownership of wild animals

The question of ownership of plants and trees is not an issue, as these are owned by the landowner while they are rooted to the ground. However, the position is different with respect to wild animals and birds, which move about freely. In South African common law, wild animals are classified as *res nullius* meaning that they are owned by nobody but fall into the category of objects which can be owned (*res intra commercium*). This contrasts with *res extra commercium*, which are things incapable of private ownership, such as the sea and sea-shore. Two conditions are necessary for ownership of a *res nullius*

object to be established; firstly that the occupier must take control of the object (*occupatio*) and secondly this must be done with the intention of becoming the owner (*animus possidendi*), e.g. if a fish inadvertently jumps into your boat, you are not its owner until you control it with the intention to possess it.

In the past, it was often difficult to establish the degree of control necessary to establish ownership of wild animals, particularly in the case of large farms through which wild animals traversed. More specifically, the problem is to establish clearly the extent of physical control that is necessary for the owner or occupier of land to become the owner of a wild animal. A second and related question is: at what point does an established owner of a wild animal lose ownership if it escapes? The ownership of wild animals has been considered in a number of reported cases.

In *Richter v Du Plooy*, (OPD, 1921) a farmer purchased a number of wildebeest and reared them by hand before releasing them onto his large farm. Subsequently, two strayed onto a neighbouring farm where they were shot. The alleged original "owner" instituted an action for damages against the neighbour, but was unsuccessful. It was held that as soon as animals escape from detention, they revert to being *res nullius* and are susceptible to *occupatio* by another. In the course of the judgment, the judge alluded to the large size of the farm and implied that this had a bearing on the juristic character of the wild animals, as they were relatively free.

The question of size of the land seemed to play a similar role in *Lamont v Heyns* (TPD, 1938), where blesbok were confined to a much smaller encampment and the perpetrator came onto the land and shot a number of the animals. The plaintiff succeeded in claiming damages. The judge appeared to take the size of the camp into account in determining that the necessary degree of control existed to constitute ownership. However, the size of the farm should not have been relevant, in view of the fact that the animals never left captivity. The general subsequent approach of the courts was that the degree of physical control required depends on the facts of each particular case.

Finally, in *Langley v Miller* (Menzie, 1848), a case concerning the acquisition of ownership of wild animals in common law, heard during a previous century, the Court had to consider the question of who was the owner

of a *res nullius*, where a series of events, rather than one event, results in its capture. In this case a whale had been harpooned by the crew of a boat and thereafter the crew of another boat assisted in the killing. It was held that each person who contributed to killing the animal was entitled to a share in its proceeds. In *R v Mafohla and Another* (SA, 1958), a hunter wounded a kudu, but it was subsequently taken into possession by a number of others. In this case, it was held that the mere wounding of an animal is not sufficient to transfer ownership by occupation and those who had subsequently captured the wounded animal *prima facie* obtained ownership by *occupatio*.

The Game Theft Act 105 of 1991

Under common law, as soon as physical control over a wild animal is lost, the animal ceases to be owned by that person and reverts to its state of natural freedom, becoming *res nullius* again. Consequently, if a wild animal escapes or is stolen, the original owner would lose any investment made in acquiring the game. The common law position was changed by the Game Theft Act 105 of 1991 (hereafter the Game Theft Act), which provided that a loss of possession does not result in the loss of ownership. However this only applies to "game" which is defined as "...all game kept for commercial or hunting purposes...(Sch 1 of the Game Theft Act)", and if the farm owner holds a valid Certificate of Adequate Enclosure issued by the provincial authority (Sch 2(2)(a) of the Game Theft Act).

The ownership of enclosed game which escapes, was in the spotlight in *Eastern Cape Parks and Tourism Agency v Medbury (Pty) Ltd t/a Crown River Safari and Another* (SA, 2016), where a herd of Cape buffalo escaped from Thomas Baines Nature Reserve onto a neighbouring safari company farm. It was contended that the buffalo were sufficiently enclosed in the nature reserve and therefore a Certificate of Adequate Enclosure was not required. It was also argued that the common law should be developed to provide that wild animals which are contained in a protected area managed by an organ of state, are *res publicae* (state property) and therefore should be afforded protection. The court found, however, that there was no basis to hold that the common law should be developed to obtain *ex post facto* protection where no certificate had been obtained. The intention

of the legislature was to limit protection against loss of ownership only in circumstances where a certificate of sufficient enclosure had been issued and that the certificate is a practical mechanism to obviate the need for an investigation into the adequacy of fencing and to avoid unnecessary disputes between landowners.

The common law position still applies to wild animals which are not "game" as defined in the Game Theft Act, for example predators such as jackal, caracal and baboon or other wild animals that are not hunted for sport or food, or farmed commercially. Wild animals which do fall within the definition of 'game' but which escape from private land to any other land for which an enclosure certificate has been issued is enclosed becomes the property of that land owner. If a wild animal kept for commercial or hunting purposes escapes from a farm that is not enclosed or does not have an enclosure certificate, then the animal is *res nullius* and not owned by anyone.

Ownership of an illegally acquired wild animal

In the *State v Frost, S v Noah* (SA, 1974), the Court had to consider a related fundamental common law question, namely: who is the owner of an illegally captured *res nullius*? Two employees of a fishing company were convicted of capturing a large tonnage of snoek during the closed season. The fish were confiscated and the accused convicted in the lower court. On appeal, the magistrate's order that the snoek be "confiscated to the State" was challenged. The Court considered various authorities, including *Dunn v Bowyer and Another* (NPD, 1926), where a hunter had been issued a licence to shoot a hippopotamus, but instead it was shot by his friend. In this case, the Court held that as the friend who had shot the hippopotamus did not hold a licence, it was not lawfully acquired. The fact that he obtained possession could not give him ownership.

The Court in the Frost case however, referred to Voet (a foremost institutional writer of Roman-Dutch law whose writings influences South African Court decisions), who expressed the view that someone who acquires a wild animal, which is a *res nullius*, unlawfully, nevertheless acquires ownership, a view which has been endorsed by Van der Merwe & Rabie (1974). This line was followed by the Court, which held that illegal capture of a *res nullius* animal nevertheless results in the acquisition of ownership.

Although the common law allows for a person to become owner of a wild animal (which is not owned by anyone), this is subject to national and provincial legislation which is severely curtails the extent to which landowners can use wild animals located on their land, and which also provides for confiscation and forfeiture of illegally acquired wildlife.

Claims for damages caused by wild animals

The courts have considered claims for damages caused by wild animals in a number of cases. In *Sambo v Union Government* (TPD, 1936), the court held that where a person introduces a dangerous wild animal onto his or her property, such person is required to prevent such wild animals from leaving his or her property and causing damage or harm elsewhere.

In contrast to this, however, in *Mbhele v Natal Parks, Game and Fish Preservation Board* (SA, 1980), it was held that that a landowner cannot be responsible for damage or harm caused by wild animals which occur naturally on the property where the landowner lets nature take its course and who takes no steps to prevent the wild animals from leaving the land. In this case, it was held it would be unreasonable and unrealistic to require a "hippo-proof" fence to be erected around the 220 km perimeter of the reserve to confine the hippos to the reserve, especially where fences would have to cross rivers and resist the forces and impacts of floods, especially given the infrequency of attacks by hippos.

Applying the reasoning of the Mbhele case, this means that where predators occur naturally (whether on private or public land) and no steps are taken or to control their numbers or behaviour, then the owner of the property has no duty to prevent the predators from escaping from the property and causing damage to others. There would be no lawful basis to claim for losses to livestock.

This is not to say that damages for losses to livestock caused by predators could not be claimed. Thus, if predators have been introduced onto the property, then there is a legal duty to control these predators and the owner (or person in control of the property), could be held liable for any losses caused by predators escaping and causing damage to livestock. However, the duty to take such measures is tempered by a consideration of the likelihood of such damages or losses being caused and

the steps that reasonably could be applied to prevent the harm from occurring.

If the owner or manager of the property from which the predator escapes denies liability and refuses to pay for the damages, then protracted and expensive court proceedings would have to be instituted to claim damages. The claimant would have a difficult evidentiary burden, as he or she would first have to establish which property the predator came from and that the owner or manager of that property should reasonably have been expected to foresee that damage or loss may occur and that reasonable steps were not taken to prevent the damage or harm (see SA, 1966). Even if successful, the cost of the legal proceedings could by far exceed the amount of damages ordered by the court, as the amount of damages would be limited to the losses proved to have been suffered. Where legislation has been enacted to regulate fencing, for example, the North West Provincial Fencing Policy, an owner may not be able to escape liability where fencing has been erected that does not comply with legislation.

Customary law

Some indigenous communities in South Africa have relied upon wild animals as resources, whether for own consumption or use, and also killing wild animals that prey on their livestock. Where these are long standing practices and are considered part of their culture, then this can be considered to be a customary right.

Customary law is recognised in the Constitution as an independent source of law which is not subject to any legislation other than the rule of constitutional law (see SA, 2003). The Supreme Court of Appeal has held that as an independent source of law, customary law may give rise to rights that include access to and use of natural resources (BCLR, 2003).

The role of customary law in respect of access to natural resources was first addressed in *Alexkor Ltd and Another v Richtersveld Community* in 2004 (SA, 2004). A community of indigenous people, the Richtersveld community successfully instituted a claim for the restoration of land. The court found that the content of the land rights held by the community must be determined by reference to the history and the usages of the community of the Richtersveld. The Constitutional Court took the view that the real character of the title

that the Richtersveld community possessed in the subject land prior to annexation was a right of communal ownership under indigenous law. The content of that right included the right to exclusive occupation and use of that land by members of the community. The court held that the community had the right to use its water, to use its land for grazing and hunting and to exploit its natural resources.

In the case of the *State v Gongqoze*, which concerned illegal fishing, the Court recognised the customary rights to fish in a marine reserve which effectively trumped the provisions of the Marine Living Resources Act (18 of 1998; MLRA). David Gongqoze and two others were jointly charged, inter alia, with entering a national wildlife reserve area (Dwesa-Cwebe Nature Reserve) "without authorization" and "specifically fishing or attempting to fish in a marine protected area in contravention of the MLRA, which prohibits fishing in a marine protected area (MPA)". In their defence the accused relied on their customary right to fish. It was also argued that the establishment of the MPA impacted negatively on the capacity of the Dwesa and Cwebe communities and other such communities to practice their system of customary law rules in respect of marine resources.

As evident from the Richtersveld and Gongqoze cases, the long standing practices of communities in regard to the use of natural resources may enjoy constitutional protection, provided that the custom is clear and has been practised over a long period.

In remote rural areas, land is typically held in trust for a tribe or community, with ownership vested in the Chief. In terms of customary law, wild animals that occur on communal land are owned by the Chief on behalf of the tribe. This would mean, in terms of customary law, the members of the tribe or community could exploit the wild animals occurring on the communal tribal land, either for own consumption or use, or to protect their livestock, provided that this use has been a long standing practice of the tribe.

Because of conflicting claims between customary rights and environmental rights, there have been calls for a community-based approach to management of wildlife that actively involves indigenous communities. The cultural practices and traditional knowledge related to wildlife could enhance the manner in which predators are controlled and managed. By adopting this approach,

communities would become involved not only in monitoring predators and managing wildlife, but would also assist authorities in compliance and enforcement of legislation. By adopting such an approach, communities that engage in farming of livestock and who are dependent on this for their livelihood would control and manage predators in a sustainable and responsible manner for the benefit of future generations (Feris, 2013).

Provincial legislation

Nature conservation and wild animal management is both a national and provincial concurrent legislative competency in South Africa. The national government has exercised its authority to impose uniform national standards and regulation of threatened or protected species, which once fell to the provinces. However, 'ordinary game' is primarily regulated by provincial authorities, although this is also a competence of the national authorities. The provincial nature conservation ordinances are in transition, many of them being updated to be consistent with the TOPS Regulations (Threatened or Protected Species) and to reflect more modern ideas about wild animals and ecosystem conservation.

As intimated in the introduction, prior to 1994, South Africa's four provinces each developed its own nature conservation and wild animal legislation and system of administration. Although provincial restructuring in 1994 expanded the four provinces to nine, the legislation itself changed very little. The nine provinces have, for the most part, retained the pre-1994 legislation and administration for regulating wild animals and the wild animal trade. In addition, prior to 1994, the former South African Independent States (Transkei, Bophuthatswana, Venda and Ciskei) had authority to develop their own nature conservation and hunting legislation that, although similar to the provincial legislation, also has some differences. Similarly, the selfgoverning territories (Lebowa, Gazankulu, KwaZulu, Qwaqwa, and KaNgwane) had limited authority to enact legislation or amend existing South African legislation on certain issues. The result was a fragmented and complex system across the Republic for regulating the use and conservation of biological resources.

Nature conservation laws in the four former provinces and homelands

It is necessary to deal with the four nature conservation Ordinances which applied in the former four provinces as well as some of the former homeland laws of the "old" South Africa, because in many cases these laws are still in place and being applied in the nine new provinces. More specifically, the four "old" Ordinances still apply as follows:

- » The Nature and Environmental Conservation Ordinance 19 of 1974 (Cape) applies to the new provinces of the Western Cape and the Eastern Cape.
- » The Nature Conservation Ordinance 12 of 1983 (Transvaal) applies in Gauteng. It previously applied to the Limpopo and Mpumalanga provinces (formerly part of the Transvaal) as well, but these two provinces have now enacted their own legislation.
- » The Nature Conservation Ordinance 8 of 1969, (Orange Free State) still operates in the Free State.
- » The Nature Conservation Ordinance 15 of 1974 (Natal) applies in KwaZulu-Natal. The more recent legislation adopted relates to the creation of institutional bodies (the KwaZulu-Natal Nature Conservation Management Act 9 of 1997, and the KwaZulu-Natal Nature Conservation Management Amendment Acts 5 of 1999 and 7 of 1999).

General approach in the provincial Ordinances

The general approach in all four provincial Ordinances is to distinguish between conservation inside and outside reserves. Outside reserves, the focus is on protecting or controlling individual species of fauna and flora, rather than ecosystems. The four ordinances do not consistently use the terms "threatened" or "endangered", but predominantly refer to categories such as "ordinary game", "protected game" and "specially protected game" and each lists individual species of wild animals, plants, birds and fish, while some include insects.

More specifically, the respective Schedules of the old Ordinances and the new provincial laws which are currently operative in South Africa provide the following categories:

- » The Nature and Environmental Conservation Ordinance 19 of 1974 (Cape) has five pertinent schedules which list the following: endangered wild animals; protected wild animals, endangered flora; protected flora; and noxious aquatic growths.
- » The Orange Free State Ordinance 8 of 1969, which applies in the Free State, lists six pertinent schedules, these being: protected game; ordinary game; specified wild animals; exotic animals; aquatic plants; and protected plants. A further Schedule, titled "Hunting at Night", list those species to which some of the hunting provisions apply.
- » The Transvaal Ordinance 12 of 1983, which applies in Gauteng, lists twelve Schedules of which the following are pertinent here: protected game (which includes a sub-schedule on specially protected game); ordinary game; protected wild animals; wild animals to which section 43 applies (this deals with possession of certain listed wild animals); exotic animals; invertebrates; problem animals; trout waters; prohibited aquatic growths; protected plants; and specially protected plants.
- » The Mpumalanga Nature Conservation Act 10 of 1998 lists fourteen Schedules which are relevant here, namely: specially protected game; protected game (which includes amphibians, reptiles, mammals and birds); ordinary game; protected wild animals; wild animals to which the provisions of section 33 (dealing with possession) do *not* apply; exotic animals to which the provisions of section 34 *do* apply (dealing with certain prohibitions); invertebrates; problem animals; fly-fishing waters; prohibited aquatic growths; protected plants; specially protected plants; invader weeds and plants; and unique communities. This Act repeals the KaNgwane Nature Conservation Act 3 of 1981.
- » The KwaZulu-Natal Nature Conservation Management Amendment Act 5 of 1999 lists four categories to which different degrees of legal protection apply, namely: specially protected indigenous animals, protected indigenous animals; specially protected indigenous plants, and protected indigenous plants.

It is evident from the above that these categories, while similar, are not the same. One of the differences is that all include the category "game", except the Cape Ordinance, reflecting the fact that hunting is not as predominant, at least in the Western Cape. However, in the Eastern Cape hunting is a large generator of revenue.

Problem wild animals

Although the various schedules to provincial ordinances are aimed at conserving indigenous fauna and flora, they are not solely protectionist. The provinces permitted and often actively encouraged the hunting of so-called "problem animals" also referred to as "damage causing animals". The Transvaal Ordinance, for example, includes a schedule of problem animals. They were previously referred to as "vermin" and included wild animals such as baboons, jackals and caracals which could be freely hunted in the past.

In the Western Cape, no permit was required to hunt damage-causing animals such as jackal and caracal before 2009. The livestock industry was essentially self-regulated, and stock and biodiversity losses increased. Three month hunting permits were issued in 2009 and this was later increased to permits valid for 6 months.

Another example of the inconsistent approach to the treatment of problem or damage-causing animals is that the African wild dog was listed as vermin in the Boputhatswana Nature Conservation Act 3 of 1973, although this was subsequently amended.

Summary

The general approach in each of these provincial laws is to protect species listed in the respective Schedules in various ways. On some, there is absolute protection; on others there are permit requirements including bag limits, specific hunting seasons, prohibitions on certain hunting methods, and so on. All these are prescribed in the respective laws, which cross-refer to the relevant Schedules.

An advantage of this provincial system is that it takes into account the different regional eco-types. A particular species may be endangered in one province, but may not exist in another province. Although the system is easily adaptable to local needs and ecological circumstances, it necessitates constant vigilance by the scientific community to monitor the status of species in

each province and therefore demands a sophisticated administrative and technical infrastructure which many of the under-resourced provinces lack.

Administration

In the old South Africa, each of the four provinces had a Department of Nature Conservation, and the former homelands also had their own respective nature conservation authorities. In KwaZulu-Natal (KZN), arguably the premier nature conservation province in the country, the position was always slightly different, in that a separate statutory board, namely the Natal Parks Board, administered conservation in the then Natal Province, from early in the twentieth century to 1997, when the Board was amalgamated with the Kwa-Zulu Bureau of Natural Resources to form the reconstituted KZN Nature Conservation Service (the KZN NCS).

The new South Africa has seen a marked trend whereby other provinces are converting their respective nature conservation departments into statutory authorities known as Boards, following the lead of the KZN NCS, and the national SA National Parks (SANParks), (formerly the National Parks Board). The first new province to do so was Mpumalanga, followed by the North West and the Western Cape.

However, the extent of these Boards' jurisdiction in their respective provinces requires consideration. Some provinces have placed only nature conservation functions (and not environmental management) under the control of their respective boards. Others are considering only placing provincial protected areas under the auspices of a board and leaving nature conservation functions outside reserves with provincial authorities.

The conservation of wild animals

Most of the provincial ordinances refer to both "wild animals" and "game" as seen above. The term "wild animal" is generally widely defined. In the case of the Cape Provincial Ordinance, for example, "wild animals" means:

"... any live vertebrate animals (including bird or reptile or the egg of any such animal, bird or reptile but excluding any fish or any ostrich used for farming purposes and the egg thereof) belonging to a non-domestic species and includes

any such animal which is kept or has been born in captivity"(Section 2 (xxiii)).

None of the provincial ordinances refers to the ownership of wild animals, therefore it is left to the common law. However, the old South West African Ordinance, which still applies in Namibia, interestingly provides that the owner of land which is adequately fenced shall be deemed to be the owner of ordinary game on that land.

The various ordinances provide for similar measures to control hunting of wild animals. Thus "endangered wild animals" may not be hunted at all according to the Cape Provincial Ordinance (Section 26), while "protected wild animals" may be hunted during the season, subject to permit requirements and conditions. The typical control measures include the laying down of hunting seasons, bag limits, prohibitions on using certain kinds of hunting methods such as fire, poison, traps, artificial lights, weapons (such as bows and arrows), and certain calibres of firearms in respect of specified species such as buffalo, eland, kudu.

Provincial reserves

Each of the provinces has declared its own provincial nature reserves. The Ordinances also provide for local nature reserves as well as private nature reserves. Where a landowner obtains approval for a private nature reserve on his or her land, he or she is generally afforded greater privileges regarding the conservation and utilisation of fauna and flora than otherwise would have been the case.

The Eastern Cape

In considering the Eastern Cape, one must also consider the Ciskei Nature Conservation Act 10 of 1987, and the Transkei Environmental Conservation Decree 9 of 1992, as these are still applicable in that part of the province which constituted the former self-governing states of Ciskei and Transkei, respectively. The Ciskei Nature Conservation Act deals with the conservation and utilisation of wild animals.

Although the Eastern Cape is still applying the Nature and Environmental Conservation Ordinance 19 of 1974 (Cape), it set in motion a number of public participation processes with a view not only to replacing the Cape

Ordinance, but also to establishing its own statutory nature conservation board. To this end, it produced a Draft Green Provincial Environment Green Paper, a decade ago. This was followed by a departmental draft Nature Conservation Bill. It is intended that this step will consolidate the nature conservation laws of the former Transkei, Ciskei and Cape Ordinance into one comprehensive Eastern Cape Nature Conservation Act. The province has also published a White Paper on the Management of Tourism, Conservation and Protected Areas in the Eastern Cape (PN 3 in *Provincial Gazette* 2277, 5 February 2010), which seeks to provide a more coherent approach to the development of tourism through conservation. The province has additionally enacted the Eastern Cape Parks and Tourism Agency Act 2 of 2010 (which repealed the Provincial Parks Board Act (Eastern Cape) 12 of 2003). The Act, *inter alia*, provides for the establishment of the Eastern Cape Parks and Tourism Agency, which is responsible for the management of provincial protected areas.

Free State

The Free State still operates under the Nature Conservation Ordinance (8 of 1969). It has, however, published the Free State Nature Conservation Bill (PN 10 in *Provincial Gazette* 23, 7 May 2010), which is intended to repeal the Ordinance when it comes into force. No further action has been taken however. The QwaQwa Nature Conservation Act 5 of 1976 is still operative in the Free State.

Gauteng

The Transvaal Nature Conservation Ordinance 12 of 1983 still applies in Gauteng. Like the other provincial Ordinances, it includes chapters on the declaration of provincial nature reserves; wild animals; professional hunting and problem animals. The "continued existence of the nature conservation advisory board" is provided for.

KwaZulu-Natal

The KwaZulu-Natal Nature Conservation Management Act 9 of 1997, established a new statutory body, the KwaZulu-Natal Conservation Board, which replaced the former Natal Parks Board and incorporates the former KwaZulu Bureau of Natural Resources to form the KwaZulu-Natal Nature Conservation Service. Despite

the repeal, certain sections the Nature Conservation Ordinance 15 of 1974 are still in place.

Limpopo Province

The position in the Limpopo Province was particularly complex because of the need to consolidate the laws and institutions of four previous homelands which existed in its area, namely Lebowa, Venda, Gazankulu and KaNgwane. This has now been done in the form of the Limpopo Environmental Management Act 7 of 2003, which replaces the old Transvaal Ordinance.

Mpumalanga

After the advent of the new South Africa, but prior to the name change of the province, Mpumalanga Province passed the Eastern Transvaal Parks Board Act 6 of 1995 (N 41 (89) *Provincial Gazette Extraordinary*, 29 September 1995) which established the Board and set out its powers, functions and related matters. Although the title of the act refers to a "Parks Board", the act encompasses nature conservation in the entire province, not only in its protected areas. The objects of the Parks Board are stipulated as being "...to provide effective conservation management of the natural resources of the Province, and to promote the sustainable utilisation thereof". Similarly the functions of the Board are stipulated to include "...inventorying, assessing and monitoring natural resources in the Province".

This province has also passed the Mpumalanga Nature Conservation Act 10 of 1998 which is a refinement of the previously applicable Transvaal Ordinance 12 of 1983, and in terms of which the Transvaal Ordinance, the Bophuthatswana Nature Conservation Act 3 of 1973; and the Lebowa Nature Conservation Act 10 of 1973 are no longer of any force or effect. The Mpumalanga Nature Conservation Act also repealed the KaNgwane Nature Conservation Act 3 of 1981 in its entirety.

The North West

The North West has passed the North West Parks Board Act 3 of 2015, which commenced in May 2015 and repeals the North West Parks and Tourism Board Act 3 of 1997. Its objects include to manage and control protected areas in the North West and to provide for nature and wildlife conservation in such protected areas, under the control and management of the North West Parks Board. The focus of this act is thus on protected

areas, rather than on nature conservation generally.

The North West has also enacted the North West Biodiversity Management Act (4 of 2016; 21 in *Provincial Gazette Extraordinary* No. 7606, 5 February 2016), which replaced a draft bill published for comment in 2016. This act provides, *inter alia*, for the management and protection of protected areas, ecosystems, and threatened and protected species. This repeals the following legislation to the extent applicable in the North West Province: Cape Nature and Environmental Conservation Ordinance 19 of 1974, Bophuthatswana Nature Conservation Act 3 of 1973, Transvaal Nature Conservation Ordinance 12 of 1983 and Cape Problem Control Ordinance 26 of 1957.

The Northern Cape

The Northern Cape previously applied the Nature and Environmental Conservation Ordinance 19 of 1974 (Cape), but this was repealed and replaced by the Northern Cape Nature Conservation Act (9 of 2009; PN 10 in *Provincial Gazette* No. 566, 19 December 2011). This act provides, *inter alia*, for "the sustainable utilisation of wild animals" as well as the implementation of CITES. It includes chapters on sustainable use of wild animals.

The Western Cape

The Western Cape continues to apply the Nature Conservation and Environmental Conservation Ordinance 19 of 1974 (Cape). In addition, it has enacted a Western Cape Nature Conservation Board Act following the trend of establishing statutory boards. The objectives of the Board include "...to promote and ensure nature conservation and related matters in the Province". The Board does not have any environmental management functions, which have remained with the Western Cape Department of Environmental Affairs and Development Planning, which is also responsible for administering the environmental impact assessment regulations under NEMA.

Summary

The provincial ordinances all distinguish between activities on and off nature reserves. While hunting occurs both on and off nature reserves, hunting is more restricted in nature reserves. Landowners, their relatives

and staff are exempt from some permit requirements when hunting on their own land. A landowner may also obtain a permit to fence his or her land and then may apply for exemption to hunt, capture and sell game in an approved fenced area. Historically, a Certificate of Adequate Enclosure in all provinces provided land owners with various rights not usually afforded to other land owners. These rights included the hunting of a species of protected wild animal specified on the permit, by any means specified in the permit, including the use of some prohibited hunting methods, the right to keep animals in captivity and the right to sell or donate any animal or carcass without a permit. However, the Threatened or Protected Species (TOPS) Regulations now invalidate these permits to the extent that they apply to listed threatened or protected species and restricted activities (Threatened or Protected Species Regulations; Notice No. R. 152; 23 February 2004; published in *Government Gazette* No. 29657 on 23 February 2007).

Most of the provinces include the category of "problem animals" or "problem species". However, the definition of these varies from province to province. The TOPS Regulations apply to the provinces that have problem animals that are on the TOPS list. Other species that are not threatened or protected but are considered to be "problem animals" will continue to be regulated by the provinces until national legislation is enacted. Most provinces (Mpumalanga, Northern Cape, Western Cape, Eastern Cape and Gauteng) allow the hunting of problem animals without a permit. In some provinces (Mpumalanga, Northern Cape, Western Cape and Eastern Cape) problem animals can be poisoned or hunted by means otherwise prohibited. While the TOPS Regulations prohibit some methods of hunting of listed threatened or protected species, for other wild animals, the method authorised for hunting or capturing is still regulated by the provinces.

To add to the complexity of this system, some provinces, such as Gauteng and the Eastern Cape have also introduced separate hunting legislation (Hunting Regulations in terms of the Nature Conservation Ordinance 12 of 1983 and the Eastern Cape Provincial Hunting Proclamation; published in Notice 22 of 2016). Hunters and compliance officials must not only be familiar with the relevant acts and ordinances but also with the legislation and policies relating to hunting. Rather than providing clarity, these policies cloud an already confusing system.

OTHER LEGISLATION

The Animals Protection Act 71 of 1962

The Animals Protection Act 71 of 1962 defines an animal to include any wild animal, bird or reptile which is in captivity or under the control of any person. The act therefore applies to all animals, including wild animals held in captivity or under the control of any person. The act specifies various acts which would constitute an offence. Conversely, an act of cruelty carried out on a predator not captured or under the control of any person would not constitute an offence.

National Environmental Management: Protected Areas Act 57 of 2003

It is increasingly accepted that the protection of species relies on the protection of the complex ecosystems. Wild animals that live in protected areas are afforded increased protection by the National Environmental Management: Protected Areas Act 57 of 2003 (Protected Areas Act) which provides for the declaration and management of protected areas. Management is defined to mean the “the control, protection, conservation, maintenance, and rehabilitation of a protected area with due regard to the use and extraction of biological resources, community-based practices and benefit sharing activities in a manner consistent with the Biodiversity Act”.

National parks are managed by SANParks and provincial protected areas are managed by provincial departments responsible for environmental matters for each province, although some provincial parks are managed by independent boards which are statutory entities.

In terms of the Protected Areas Act, the State acts as trustee of protected areas in South Africa. The management of a protected area must be conducted in accordance with the management plan approved for the area by the Minister or MEC following the consultation with relevant organs of state, municipalities, local communities and other affected parties. The object of the management plan is to ensure that the protection, conservation and management of a protected area is taking place in a manner which is consistent with the Protected Areas Act and for the purpose for which the area was declared.

Under the Protected Areas Act wild animals enjoy a measure of protection. Various provisions require the written authority of the management authority of the area, to: intentionally disturb or feed any species, to hunt, capture or kill; to possess or exercising physical control over any specimen; and conveying, moving or otherwise translocating any species. The maximum penalty is a fine or imprisonment for a period not exceeding five years or to both such fine and such imprisonment. The amount of the fine is not specified and will depend on the nature of the offence committed and the jurisdiction of the court where the matter is heard.

National Environmental Management: Biodiversity Act 10 of 2004

The main objectives of the National Environmental Management: Biodiversity Act 10 of 2004 (Biodiversity Act) are to provide for the management and conservation of South Africa’s biodiversity; the use of indigenous biological resources in a sustainable manner; and the equitable sharing among stakeholders of benefits arising from bio-prospecting involving indigenous biological resources. The Biodiversity Act also deals with the protection of threatened or protected species.

Species that are considered to be of high conservation value or national importance that requires national protection are listed as being a “threatened or protected species” and can be listed as (a) critically endangered (indigenous species facing an extremely high risk of extinction in the wild in the immediate future; (b) endangered (indigenous species facing an extremely high risk of extinction in the wild in the near future, although they are not a critically endangered species; (c) vulnerable (indigenous species facing a high risk of extinction in the wild in the medium-term future, although they are not a critically endangered species or an endangered species; or (d) protected (indigenous species of high conservation value or national importance that require national protection).

The Biodiversity Act prohibits the carrying out of any restricted activity involving a listed species without a permit. Any activity which may negatively impact the survival of a listed threatened and protected species may also be prohibited.

Although permits are issued to kill or otherwise

control (or engage in any restricted activity) of species listed as threatened or protected, the issuing authority can issue the permit with onerous conditions and can also require that the applicant furnish to it in writing, at the applicant's expense, an independent risk assessment or such expert evidence as the issuing authority may determine necessary. The Biodiversity Act is framed in such a manner that the issuing authority can make it too expensive for an applicant to obtain and submit further information and reports that it may require, or too difficult to comply with the conditions of the permit.

It is an offence for any person to conduct a restricted activity in respect of the Biodiversity Act. The penalty for engaging in a restricted activity in respect of species listed on TOPS without a permit has been significantly increased. A person who hunts, captures, kills, imports, exports, trans-locates, conveys, moves or sells or trades a listed predator without the necessary permit will face a maximum penalty of imprisonment not exceeding ten years or a fine not exceeding R10,000,000. In addition, the court can order the person convicted to pay the reasonable costs incurred by the public prosecutor and the organ of the state concerned in the investigation and prosecution of the offence.

Threatened or Protected Species Regulations

Introduction of a uniform permit system

The primary objectives of the TOPS Regulations are to: establish a national permit system for species that are listed as threatened or protected; provide for the registration of game farms; captive breeding operations and other facilities; regulate hunting (which is a "restricted activity"); prohibit certain activities involving specific listed threatened or protected species; and provide for the protection of wild populations of listed threatened or protected species.

The permit system applies to all restricted activities (including hunting) involving threatened or protected species. A permit is required to hunt, catch, capture, kill, import, export, be in possession of or exercise physical control over, breed, convey, move or otherwise translocate, sell or otherwise trade in, buy or in any way acquire or dispose of listed species.

Further when assessing an application for a permit,

the issuing authority must consider factors such as the categorisation of the species listed, whether the species is listed on the IUCN Red Data List, whether the species belongs to a wild population; the biodiversity management plan for the species; any risk assessment report or expert evidence by the issuing authority; and whether the applicant has had other permits cancelled before.

Regulation of the hunting industry

Historically the hunting of ordinary game and threatened or protected species was dealt with by the provincial authorities. Inevitably, this led to the inconsistent treatment of threatened or protected species and the standards of protection given to endangered species varied between provinces. The TOPS Regulations introduced uniform standards and prohibited methods that were considered inhumane and contrary to the principles of a fair hunt. However, these regulations only apply to the species listed as threatened or protected under the Biodiversity Act. The hunting of ordinary game remains the responsibility of the provinces. If there is a conflict between the TOPS Regulations and any provincial legislation, the national legislation (being the TOPS Regulations) will prevail over provincial legislation.

In considering an application for a hunting permit, the issuing authority must take into account factors such as whether the applicant is a member of a recognised hunting organisation application and whether permission is sought to engage in a prohibited method of hunting. Importantly, the TOPS Regulations make provision for the recognition of hunting organisations and the application of codes of ethical conduct and good practice. Hunting organisations that have been recognised are required to ensure that their members comply with the hunting regulations and must report any illegal hunting of species listed as threatened or protected.

To a large degree, monitoring and control of hunting activities is exercised by self-regulation. The holder of the hunting permit is required to have all permit documents in his or her possession at the time of the hunt and to furnish a return of the hunt to the issuing authority within 21 days of the hunt specifying the permit number, date of issue, species, sex and number of animals hunted, and location where the hunt took place.

The TOPS Regulations impose prohibitions and

restrictions on certain hunting methods involving “listed large predators”, namely cheetah, spotted hyena, brown hyena, African wild dog, lion and leopard. The regulations also prohibit hunting listed threatened and protected species with dogs, poison, snares and traps. Hunting with bright lights, luring sounds, baits and use of vehicles is also prohibited as these offend the principle of 'fair chase'. However, these prohibited methods do not apply to threatened or protected species that are damage-causing animals.

The TOPS Regulations allow the use of bait in hunting damage-causing animals that are listed threatened or protected species. This includes lions, hyena and leopard and the use of floodlights or spotlights is also permitted.

Prior to the enactment of the TOPS Regulations, the hunting of damage-causing animals was authorised by the provincial authorities. This resulted in many species being hunted without restriction, often resulting in non-target species being killed and inhumane methods being utilised. The TOPS Regulations introduced a requirement that a listed threatened or protected species can only be deemed to be damage-causing if there is substantial proof that the animal causes losses to stock or wild animals; excessive damage to trees, crops or other property; threatens human life; or materially depletes agricultural grazing. This requires the provincial authority to determine whether a listed threatened or protected species is in fact a damage-causing animal.

The TOPS Regulations provide various options for controlling a damage-causing animal if it emanates from a protected area: capture and relocation; culling by the provincial authority; or capture and relocation by a person authorised by the provincial authority (other than a hunting client). In determining which option to authorise, the regulations provide that killing the animal must be a “matter of last resort”.

A landowner is entitled to kill a damage-causing animal in self-defence where human life is threatened - however this does not extend to killing an animal to protect livestock or domestic animals. If a damage-causing animal is killed in an emergency situation, the landowner must inform the relevant issuing authority of the incident within 24 hours. The issuing authority is required to evaluate the evidence, and if it finds that the killing was justified, it must condone the action in writing or if necessary, take appropriate steps to institute

criminal proceedings, if not justified.

A permit holder can be authorised to hunt a damage-causing animal by the following means: poison (provided this is registered for poisoning the species involved and is specified in the permit); bait and traps (excluding gin traps), where the damage-causing animal is in the immediate vicinity of the carcass of domestic stock or wildlife which it has killed; the use of dogs, (for flushing the damage-causing animal or tracking a wounded animal); darting (for the subsequent translocation of the damage-causing animal); and the use of a rifle (or firearm suitable for hunting purposes). The permit may also authorise hunting a damage-causing individual by luring by means of sounds and smell, and may also hunt a damage-causing animal by using a vehicle with floodlights or spotlights.

Certain hunting methods are also prohibited. This includes hunting by poison, traps, snares, automatic rifles, darting (except for veterinary purposes), shotgun, air gun or bow and arrow. The use of floodlights or spotlights, motorised vehicles or aircraft for hunting is also prohibited unless this is required to track a predator over long ranges or to cull and is specifically authorised.

The failure to be in possession of a valid permit is a criminal offence, the penalty for which is a fine of R100,000 or three times the commercial value of the specimen in respect of which the offence was committed, whichever is the greater, or to imprisonment for a period not exceeding five years or both.

Draft Norms and Standards for the Management of Damage-Causing Animals

In terms of the Biodiversity Act, the Minister may, by notice in the Government Gazette, issue norms and standards to manage and conserve of South Africa's biological biodiversity and its components or to restrict activities which impact on biodiversity. In announcing the first draft Norms and Standards (published in 2004), the Minister responsible for Agriculture, Forestry & Fisheries, revealed that losses caused by predation to sheep or small stock sectors eclipsed losses attributed to stock theft. The Minister also stated that the loss of livestock "is contrary to the objectives of the Africa Livestock Development Strategy if left unattended." It is against this backdrop that the draft Norms and Standards was

published by the Department of Environmental Affairs in November 2016 (Government Gazette No. 40412 dated 10 November 2016, under General Notice No. 749).

The purpose of the draft Norms and Standards is to set national standards for a uniform approach to the application of management interventions in order to prevent or minimise damage to livestock or wild animals; cultivated trees, crops or other property; or to prevent imminent threat to human life, with minimum adverse effect to the damage-causing animal; appropriate and effective management interventions or equipment which should be implemented by adequately trained persons, organizations, registered businesses, practitioners, conservation authority or issuing authority; and minimum standards

- i. to assist the issuing authority in the development of legislation and/or policies to regulate the management of damage-causing animals; and
- ii. for the lawful use of methods, techniques or equipment to manage damage-causing animals.

However, the draft Norms and Standards only apply to wild vertebrate animals that are regulated either by the TOPS Regulations or by provincial legislation. The draft Norms and Standards do not apply to vertebrate animals not listed on TOPS (such as bush pigs and baboons), or to domestic animals that have become feral. A practical difficulty is that the draft Norms and Standards apply to damage-causing animals that cause "substantial loss to livestock or to wild animals". This determination will depend on the assessment of an official of the issuing authority who is required to determine the severity of the damage caused by considering the following criteria:

- i. actual loss of life or serious physical injuries;
- ii. imminent threat or loss of life or serious physical injuries;
- iii. actual loss of livelihood, revenue or property;
- iv. potential loss of livelihood, revenue or property.

Following the assessment of the severity of damage caused, an inspection report must be compiled and based on the information contained in the report, the issuing authority must propose the most appropriate management intervention to minimise the damage

which can include live capture and killing. The norms and standards set out parameters for translocation and deterrent measures such as fencing, the use of collars, herding techniques, repellents and the minimum requirements for restricted methods. These regulate the use of cages, poison collars, darting, call and shoot, foothold traps, the use of hounds, the use of poison firing apparatus and denning (the removal of pups and/or adults from black-backed jackal dens).

Methods of controlling damage-causing animals under the draft Norms and Standards that are in conflict with the Animals Protection Act 71 of 1962 may be unlawful, for example, hunting with dogs, the use of traps, poisons, lures and denning. Under the draft Norms and Standards, the use of dogs is a restricted method that can only be used on the authority of a permit and "only for the purpose of pursuing or tracking a wounded damage-causing animal or flushing, pointing and retrieving a damage-causing animal." This provision undermines the cultural practice of indigenous groups who have a long standing tradition of hunting with dogs, as well as farmers embracing the English tradition of fox hunting on horseback accompanied by dogs.

The draft Norms and Standards impose significant administrative burdens on the issuing authority which may be unworkable in practice. For example, the damage caused by the predator must first be assessed and then an inspection report compiled before appropriate measures to control predator can be authorised. In addition, the draft Norms and Standards contemplate that any authorisation will be subject to various conditions that must be complied with. Many of the provisions are impractical. For example, a person who is lawfully authorised to use a cage trap must be adequately trained - but there is no guidance as to the training necessary or how this will be assessed. A cage trap must be set in the shade and as close as possible to where the damage was caused and the trap must be inspected and approved prior to the placement of cage trap being set.

It is unlikely that there are adequate resources in place. To implement the draft Norms and Standards, the Provincial Authorities will have to employ sufficiently trained officials to assess the damage to livestock caused by predators, compile the necessary inspection report and then process and issue the authorisation and then

also monitor compliance. There are no time periods within which applications must be processed and permits issued. The inevitable delays in issuing the required authorisation will only lead to an increase in tension between livestock farmers and the authorities and likely result in livestock farmers taking matters into their own hands.

The draft Norms and Standards contemplate that a conservation authority may develop a compensation strategy for the payment of compensation to a person who has suffered loss or damages caused by a damage-causing animal. Although the payment of compensation will be encouraged by livestock farmers, the manner in which this is calculated should be easily determined and quantifiable if this is to in any way benefit livestock farmers. However, even if a practical and workable compensation process is implemented, it is unlikely that the provincial authorities will have sufficient financial resources to properly compensate livestock farmers.

A case-by-case approach to dealing with individual damage-causing predators will not address the challenges faced by stock farmers. It could take at least thirty days for the evaluation report and permit to be issued to control a specific predator. If there is no efficient system for permits to be issued to regulate and control predators, this will inevitably result in livestock farmers taking matters into their own hands and adopting unregulated measures to kill or otherwise control predators.

In conclusion, the South African Game Conservation Association (an NGO) has called for wildlife to be managed on an ecological systems-based approach that assesses the causes of conflict between livestock farmers and predators. This ecosystem approach requires an assessment of all wildlife in a particular area, including predator behaviour caused by environmental changes. Provincial authorities, in consultation with affected livestock farmers should define a geographical area for the management of predators at a local level.

As envisaged under this call, a management plan for each identified geographical area should be drawn up with input from livestock farmers and other interested and affected parties. The plan should identify and list all the predators that cause damage to livestock and to determine (a) the number of predators of a damage-causing species and their vulnerability as determined by the IUCN classification; (b) the degree to which they are

considered to cause damage to livestock; (c) the food sources of the predators; (d) the range of responsible measures that could be employed by livestock farmers to control the predators without a permit (including the number of that may be culled in a given period; and (e) the reporting requirements of livestock farmers. The plan should also assess whether income can be generated through consumptive use, for example by professional hunting. To be effective, the plan would require input from experts in ecology and regular assessment and review. The management plan, together with the list of species and range of measures should be revised on an *ad hoc* basis when necessary to ensure that the plan is kept updated and in line with relevant best practice.

If appropriate management plans for the control of predators are developed with input from livestock farmers, it is likely that livestock farmers would accept the plan and only implement approved measures to control predators. Routine inspections should be carried out by Provincial authorities to monitor and enforce compliance.

A management plan for the control of predators developed for local geographical areas with proper consultation from livestock farmers will reduce the administrative burden on provincial and national authorities as well as reduce the detrimental impact of unlawful measures, such as poisoning, from being implemented.

CONCLUSION

In terms of the Biodiversity Act, any person, organisation or organ of State desiring to contribute to biodiversity management may submit to the Minister for his or her approval, a draft biodiversity management plan for an indigenous species listed as a TOPS species. Biodiversity management plans for the control of predators should be developed on an ecosystem based approach for local geographical areas with proper consultation from livestock farmers and local communities. The draft Norms and Standards should be comprehensively revised to allow for permits to be efficiently issued for the control of damage-causing animals. This will reduce the administrative burden on provincial and national authorities, as well as minimise the detrimental impact of unlawful measures, such as poisoning, from being implemented.

The Protected Areas Act, Biodiversity Act and TOPS Regulations do not address the issue of ownership of escaping wild animals, nor do these provide a mechanism for dealing with the financial implications of damage caused to livestock by escaping predators. To reduce the burden on farmers of having to prove that the loss to livestock was caused by specific predators, legislation should be amended to provide that where specified measures are not taken to control the movement of damage-causing predators, the State should be responsible for all damage caused to livestock by predators escaping from protected areas, and owners of private land who have introduced wild animals should similarly be responsible if they have not taken prescribed measures to contain these animals.

The provincial authorities, which are responsible for implementing the TOPS Regulations as well as provincial

legislation, must bring the provincial legislation into line with the Protected Areas Act and the Biodiversity Act to ensure a cohesive legislative framework.

At present, contraventions of South African environmental legislation are primarily criminal offences which require an offender to be prosecuted and if the commission of the offence is proved beyond a reasonable doubt, the court will impose an appropriate fine, or even imprisonment. This places an undue strain on an overburdened criminal justice system which does not have a high prosecution success rate. To encourage compliance, particularly with the Biodiversity Act and relevant provincial legislation relating to wild animals, the legislation should provide for an administrative penalty system for the contraventions and for the determination of a monetary penalty (having regard to a range of factors).

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PAST AND CURRENT MANAGEMENT OF PREDATION ON LIVESTOCK

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INTRODUCTION

The causes of human-predator conflict (HPC) are typically viewed from an anthropocentric perspective (see Redpath et al., 2013) and are consequently translated into costs incurred by humans through various animal behaviours (Aust, Boyle, Ferguson & Coulson, 2009; Barua, Bhagwat & Jadvav, 2013). Instances of HPC may originate where predators prey on livestock (Wang & Macdonald, 2006; Chaminuka, McCrindle & Udo, 2012), utilise resources of recreational value (Pederson et al., 1999; Skonhofs, 2006), damage human property (Gunther et al., 2004), pose a threat to the safety of humans (Loe & Roskaft, 2004; Thavarajah, 2008), or compete with other species of conservation or economic value (Engeman, Shwiff, Constantin, Stahl & Smith, 2002). In response, humans employ a range of management strategies to moderate the costs that they incur from HPC.

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WHILE many predation management strategies have shown some success in reducing livestock losses (Linnell, Swenson & Andersen, 2001), negative consequences of predation management have also been demonstrated, including: (1) the extinction or near extinction of predators in certain areas because of eradication programmes (Woodroffe & Ginsberg, 1999; Treves & Karanth, 2003; Bauer & Van der Merwe, 2004; Skead, 2007; 2011; Chapter 2); (2) the alteration of ecosystems and apparent increases in the numbers of some primary consumers and/or meso-predators where predators were excluded or eradicated (Estes, 1996; Ripple *et al.*, 2014; Chapter 8); (3) threats to populations of non-target species because of non-specific management techniques (Glen, Gentle & Dickman, 2007; also see “Predation management methods”); (4) counter-productive predation management approaches, with more livestock losses occurring after their implementation (Allen, 2014; Treves, Krofel & McManus, 2016); and (5) the straining of relationships between livestock producers, different sectors of society and policy makers (Madden, 2004; Thompson, Aslin, Ecker, Please & Tresrail, 2013; Chapter 4).

However, without predation management, the economic viability of livestock farms may be threatened and this can negatively affect local and regional economies (Jones, 2004; Feldman, 2007; Strauss, 2009; Allen & West, 2013; Chapter 3). In South Africa, approximately 80% of land area is used for livestock farming (Meissner, Scholtz & Palmer, 2013). The country is also a signatory to a number of global commitments to biodiversity conservation (Chapter 5). Thus, it is important to implement predation management strategies that ensure both a sustainable livestock industry and promote biodiversity and ecosystem conservation (Avenant & Du Plessis, 2008). It is also important to account for the religious and cultural norms of the specific area where predation management is applied (Thirgood & Redpath, 2008; Dickman, 2010).

In this chapter, we assess the various predation management methods used in South Africa and internationally and consider their application in the South African context. We focus on the effectiveness of each method.

PREDATION AND PREDATION MANAGEMENT APPROACHES USED INTERNATIONALLY

Predation management strategies around the world have similar broad objectives but vary markedly at the level of implementation because they are governed by different economic, political and legal frameworks and occur in different ecological and cultural settings. Where predation management is used to protect livestock, the livestock production setting and scales of operation can also vary enormously. At a global level, three broad predation management strategies are used: eradication or exclusion, regulated harvest or suppression, and preservation or coexistence (Treves & Karanth, 2003). The relative reliance on each strategy varies in accordance with governance structures or what is mandated by specific laws. In addition, this reliance is also influenced by the complex and constantly shifting interplay of various factors including cost effectiveness, practicality, feasibility, environmental consequences and social acceptance at both local and national scales.

Predator management in many parts of the world was originally used as a means to ensure continued hunting opportunities in conjunction with reduced predation of livestock. Not surprisingly, early attitudes of wildlife managers and policies focused on predator control (e.g. Beinart, 1998; Stubbs, 2001; Feldman, 2007; Chapter 2). State sponsored eradication of predators and harvesting through hunting has, however, declined in many parts of the world due to increasing pressure from animal welfare organisations and conservationists (Zinn, Manfredo, Vaske & Wittman, 1998). Simultaneously, non-lethal methods linked to conservation strategies have gained favour in some areas, despite the complexity and costs associated with their implementation. Wildlife managers are increasingly expected to balance the demands of protecting predators from people, and people and their livestock from predators (Treves & Naughton-Treves, 2005; Treves, Wallace, Naughton-Treves & Morales, 2006; Redpath, Bhatia & Young, 2015). Evidence for whether such compromises are cost-effective and sustainable in the long term and whether they are scalable for use in extensive farming is however poor (Madden, 2004; Inskip & Zimmerman, 2009; Treves *et al.*, 2016; Eklund, Lopez-Bao, Tourani, Chapron & Frank, 2017; Van Eeden *et al.*, 2017).

The dearth of appropriate case-control study designs, complex socio-political landscapes and historical idiosyncrasies have together promoted diverse responses to global predation management strategies. In North America, wildlife is publically owned and managed by the state/province with both hunters and public taxes generally providing the money for state-funded management of predation (e.g. population census, setting of hunting quotas) (Geist, Mahoney & Organ, 2001; Heffelfinger, Geis & Wishart, 2013). This approach generates substantial income for local economies, promotes public interest in both consumptive and non-consumptive use of predators and, for the most part, has promoted robust predator populations while keeping livestock losses at apparently acceptable levels (but see Peebles, Wielgus, Maletzke & Swanson, 2013; Teichman, Cristescu & Darimont, 2016). Damage causing predators in the United States (US) are managed under the “Integrated Wildlife Damage Management Program” with appropriate and approved management methods that consider environmental impacts, social acceptability, the legal framework and the costs involved (Bodenchuck, Bergman, Nolte & Marlow, 2013). Importantly, the various wildlife management agencies in the US also engage in applied research relevant to predation management and develop methods of particular relevance for mitigating HPC (Bodenchuck *et al.*, 2013).

The Australian model is similar to that of North America, as the government owns and assumes responsibility for predation management and works with states/territories to develop conflict mitigation strategies, undertake research and fund essential management activities (Downward & Bromell, 1990; Allen & Fleming, 2004; Fleming *et al.*, 2006; Anon. 2014; Fleming *et al.*, 2014; Wilson, Hayward & Wilson, 2017). Individual property owners can use a variety of lethal and non-lethal methods (Fleming *et al.*, 2014). Control techniques for damage causing animals include extensive state-managed poison baiting (using 1080 or sodium fluoroacetate) programmes and the 4600 km Dingo Barrier Fence (DBF), that aims to exclude dingoes *Canis dingo* or feral dogs *Canis familiaris* from the entire south-eastern section of the continent (Yelland, 2001). Extensive poison baiting, including the use of aerial drops, is considered acceptable in Australia because many native species have a much higher tolerance to

1080 than introduced species, such as European red foxes *Vulpes vulpes*, feral cats *Felis catus*, European rabbits *Oryctolagus cuniculus* and dingoes or feral dogs (McIlroy, 1986; APVMA, 2008). Additionally, bounties have been used throughout Australia to control “pest” species, and continue to be used in some areas, usually with little to no effectiveness for decreasing livestock predation (Hrdina, 1997; Glen & Short, 2000; Harris, 2016).

Similar to the US and Australia, predation management in Europe initially focused on eradication, with bounties paid for predators killed with unselective trapping, shooting and poisons (Schwartz, Swenson & Miller, 2003). However, unlike the US and Australia, countries in Europe do not have central authorities for managing damage causing animals, which are largely managed on a case-by-case basis. More recently, there have been attempts to establish a framework for the reconciliation of human-predator conflicts, with many European countries affording protected status to large predators in an effort to stimulate their recovery (Zimmerman, Wabakken & Dotterer, 2001; Chapron *et al.*, 2014). Members to the European Union also endorsed the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and the Habitat Directive of the European Union committed to the protection of endangered or endemic species and natural habitats, forcing governments to get actively involved with the management/conservation of various predator species (Andersen, Linnell, Hustad & Brainerd, 2003; Epstein, 2013). Consequently, non-lethal methods such as livestock guarding animals and compensation for livestock losses are now widely used in Europe, and hunting predators is highly regulated and/or prohibited (Cuicci & Boitani, 1998; Stahl, Vandel, Herrenschmidt & Migot, 2001; Treves *et al.*, 2017).

By contrast, in many parts of Asia and East Africa (e.g. Kenya), although wildlife is state owned, there is a heavy reliance on tourism to provide revenue for predation management (Kellert, Mehta, Ebbin & Lichtenfeld, 2000; Mburu, 2007). Hunting is often prohibited on the grounds that it is detrimental to wildlife populations and unethical. In addition, with limited incentives for the public to invest in wildlife, many large mammal populations are declining rapidly and levels of conflict around protected areas are high (Ripple *et al.*, 2014; 2015). Of concern is that most people living in these

regions are subsistence farmers with low income levels and are thus more likely to experience greater impacts from damage causing predators than commercial farmers or urban dwellers (Peterson, Birkhead, Leong, Peterson & Peterson, 2010). In less developed countries, most damage mitigation measures involving predators are community based and lack the resources for coordinated and extensive predator management programmes. In India, where conflicts are chronic and threaten lives and livelihoods, the local authority may permit any person to hunt a “problem animal”, if satisfied that the animal (from a specified list) has become dangerous to human life, or is so disabled or diseased that it is beyond recovery.

Context for the South African situation

Unlike the North American, central African and Asian models for predation management, most southern African countries (e.g. Namibia, Zimbabwe and South Africa) have seen the devolution of wildlife rights to private landowners and local communities (Wilson *et al.*, 2017). This places the burden of managing damage causing animals on the individual, but also allows the profits of both consumptive and non-consumptive tourism and wildlife sales to be accrued by the individual. Historically, South Africa is similar to the rest of the world in that it has seen the transitions from a hunter-gatherer system to nomadic pastoralism and ultimately sedentary agriculture, corresponding with a progressive elimination of large predators from much of their historical distribution (Chapter 2). Bounty systems and systematic state-sponsored poisoning of predators provided parallels with the Australian, North American and European systems in the late 1800’s (Beinart, 1998; Nattrass & Conradie, 2015).

State-sponsored support for farmers in conflict with predators shifted to extensive fencing in the later 1800s (Beinart, 1998; Nattrass & Conradie, 2015; Chapter 2) and was later combined with state-sponsored hunting clubs to eradicate predators from within fenced areas. For a while, the impacts of predators on livestock appeared to have been ameliorated (Nattrass & Conradie, 2015) and the combination of state-sponsored extensive fencing, poisoning and hunt clubs provided close parallels with the Australian approach to predator control, differing from the US and Europe primarily in the extent of the reliance on fencing. Similar to the US Wildlife Services,

the state also funded (limited) predator management research and offered farmer training.

From the mid 1990’s, the responsibility of managing predators in South Africa was almost entirely devolved to private landowners, with state-subsidized hunting clubs phased out and dedicated facilities closed down (Du Plessis, 2013). National and provincial authorities now only provide a legal framework within which landowners can protect their stock, offer advice on the range of legal methods for mitigating conflict and managing stock, and manage permitting for research applications from Non-Governmental Organisations (NGO) and tertiary institutions. In the absence of state-funded and coordinated wildlife management outside of protected areas, South African farmers were effectively on their own and increasingly reliant on sectoral organisations (e.g. the Predator Management Forum - PMF), academic institutions and NGOs for advice and advances in understanding and mitigating livestock losses to predators. The livestock farming landscape in South Africa has also changed significantly in recent years, with many small stock producers switching to cattle or game and others ceasing to farm altogether, a trend similar to that observed in Australia (Allen & West, 2013; 2015). Additionally, many livestock farms have converted to so-called “weekend” or absentee farms (Du Plessis, 2013; Nattrass & Conradie, 2015). The result is that in many instances, predation management now occurs in isolation and on relatively small scales (\approx on a single farm or farm consortium) rather than collectively.

In the absence of state-coordinated predation management and research, it is not surprising that management and policy are largely reliant on opportunistic and descriptive research derived from adaptive management outcomes, often at the level of individual farms (Du Plessis, 2013). The lack of appropriate case-control study designs for both lethal and non-lethal predation management is a major impediment to deriving management strategies that can be scientifically and publicly defended (Kerley *et al.*, 2017). As a consequence, there can be intense contestation among increasingly diverse stakeholders as to what works, where and why (Du Plessis, 2013; Nattrass & Conradie, 2015). Some aspects of the debate are political and intertwined with power relations as well as personal value systems (Raik, Wilson & Decker, 2008). With a

growing acceptance that ultimately wildlife management is strongly linked to people management (Redpath *et al.*, 2015), there is also increasing awareness of the need to focus more on human behaviour and attitudes; in order to address chronic conflicts and understand the socio-economic factors that influence how society produces food relative to wildlife populations (\approx human dimension of wildlife management – Miller, 2009).

PREDATION MANAGEMENT METHODS

Globally humans have developed an array of techniques to respond to both perceived and real impacts of predation on livestock (Table 6.1, see following page). These techniques consist of lethal and non-lethal methods and are generally implemented as a precautionary (\approx preventative) measure to decrease the risk of livestock predation or as a remedial (\approx reactive) action following predation (PMF, 2016). In South Africa, many livestock producers persist in attempting to reduce predator numbers through unselective, lethal methods (Du Plessis, 2013; McManus, Dickman, Gaynor, Smuts & MacDonald, 2015; Minnie, Gaylard & Kerley, 2016). There are, however, an increasing number of producers who are moving away from an eradication-only approach to non-lethal and more target-specific methods (Minnie, 2009; Van Niekerk, 2010; Du Plessis, 2013; Badenhorst, 2014; Humphries, Hill & Downs, 2015; McManus *et al.*, 2015; Schepers, 2016). Some South African farmers even indicate that they do not actively kill predators, but rather focus on stock and rangeland management to manage livestock predation (Van Niekerk, 2010; Humphries *et al.*, 2015; McManus *et al.*, 2015).

Although communal livestock farmers in South Africa generally make use of animal husbandry practices and disruptive deterrents, a recent survey found that ca. 25% of communal livestock farmers surveyed across South Africa indicated they would use lethal methods such as traps and hunting to control depredation if they had the resources to do so (Hawkins & Muller, 2017). This was most pronounced in the low-income area of the Eastern Cape where 95% of livestock owners wished to use lethal methods. In the same study, tolerance to livestock loss was strongly negatively correlated with both the degree of livestock loss and income. The same

group remained “extremely angry” after a perceived depredation event and did not find the loss acceptable, despite 40% indicating that they were unsure the loss was due to a predator. Poverty, limited access to resources, unemployment and weak education are common problems on communal rangelands (Bennett, Solomon, Letty & Samuels, 2013). In South Africa, several governmental (e.g. Expanded Public Works Programme) and non-governmental programmes (e.g. Conservation South Africa’s Meat Naturally Initiative; Meat Naturally Pty) are aimed at creating wealth and capacity in rural populations.

For the purpose of this chapter, we characterise the range of predation management techniques into seven groups: (1) disruptive deterrents (or primary repellents) which disrupt predator behaviour through a number of mechanisms such as neophobia (fear of novel items), irritation, or pain (Shivik, Treves & Callahan, 2003); (2) animal husbandry practices which include methods that shelter livestock from predation (Shivik, 2006); (3) aversive deterrents (or secondary repellents) which deliver a (negative) stimulus in synchrony with a target species’ particular behaviour with such regularity that the species learns to associate its behaviour with the stimulus (Shivik *et al.*, 2003); (4) provisioning (supplementation) which provides additional food resources to predators in an attempt to deter them from killing livestock (Steyaert *et al.*, 2014); (5) non-lethal population control which aims to suppress or decrease predator population growth or numbers, without killing them (Dickman, 2010); (6) producer management which aims to compensate a livestock owner who has suffered livestock losses as a result of predation (Dickman, 2010); and (7) lethal predator management which aims to eliminate either individual predators or entire predator populations (Dickman, 2010).

Table 6.1. Summary of the available predation management methods and their potential application in the South African context.

Response ^a Method	Description	Effectiveness ^b	Pros ^c	Cons ^c	Countries practiced/ studied ^d	Application for SA			Available information ^e	
						PR	SC	A		
Disruptive deterrents/ Primary Repellents	Normal fladry	Effective against wolves, but not coyotes, for between 1 to 60 days	Rapid implementation; immediate success	Needs to be extensively installed; animals habituate quickly; not as effective for less territorial species or dominant individuals	North America; South Africa	Could be used for short periods, e.g. lambing seasons (recommended for periods less than 14 days)	Y	Y	Y	Y
	Electrified fladry	Effective against wolves for up to 90 days	Rapid implementation; effective for longer periods compared to normal fladry	Needs power; animals may habituate; high maintenance and installation costs	North America	Could be used for short periods, e.g. lambing seasons (recommended for periods less than 14 days); potential high costs may limit its cost-effectiveness	Y	N	N	N
	Human herders	High with smaller flock sizes and smaller ranges	Improved husbandry and veld management; can make direct observations	Impractical in low density, extensive livestock farming operations, and where labour is expensive; predators may become used to the herdsman and attack when livestock most vulnerable	East Africa; Europe; US; South Africa	Likely to be effective in most farming areas; high costs may limit its use in wide-spread farming areas with low densities of livestock; opportunity for job creation (e.g. Jobsfund; EPWP)	Y	Y	Y	Y
	Guarding dogs	High for most predator species in most circumstances	Long-term provided guard dogs are well trained	Considerable expertise required for training; daily feeding; may attack other wildlife, susceptible to extreme heat and disease/ticks	Australia; Botswana; Europe; Namibia; South Africa; US	Likely to be effective in most circumstances, given the correct training and care is provided; especially when used in conjunction with well maintained fence system	Y	Y	Y	Y
	Other guard- ing animals	Efficiency to deter predators may differ depending on the size, alertness and leadership qualities of the individual	No need for extra feeding; easier to bond with livestock	Alpacas & llamas expensive; may harass livestock; may negatively impact breeding behaviour	Australia; Namibia; South Africa; US	Likely to be effective in many circumstances, given the correct individuals are introduced	Y	Y	Y	Y
	Cellular technology	Unknown	Provides remote information on flock/herd status	Needs GSM coverage; there are response time limitations and false alarms; ineffective in extensive areas where farmers are not able to reach their stock quickly	South Africa	Can work in most farming areas, but its feasibility may be limited by its inability to transfer a signal in extensive areas where stock cannot be reached quickly	Y	Y	Y	Y

^a see "Predation management methods" for a description; ^b effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; ^c including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; ^d examples based on the literature included in "Predation management methods"; ^e type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

Husbandry practices		Disruptive stimuli	Flickering lights and acoustic cues associated with human activity	Effective against a variety of species for short periods	Initially easy to set up and use; can be effective in targeted species specific application	Rapid habituation; devices can be expensive to buy and running costs high; difficult to scale up on large properties	Australia; Kenya; South Africa; US	Can be used as an addition to other techniques for short periods; may not work for all predator species; more successful in small areas; currently not recommended for more than two weeks at a time	Y	Y	Y
	Protection collars	Physical protection against neck bites (including bell and poison collars)	Only effective for throat bites and only for limited periods	Easy to use and apply; targets damage causing predators only; no impact on other wildlife (except where poison collars are used and poison gets ingested by non-target wildlife)	Predators get habituated to protection collars and attack the hindquarters; expensive to apply to all stock; intensive management; needs regular adjustment	Norway; South Africa; US	Can be used in addition to other techniques for shorter periods; may not work against all predator species; not recommended for more than two weeks	Y	Y	Y	
	Predator proof fencing	Physical separation of predators and livestock by utilizing a fence designed to keep predators out	Generally effective at excluding most canids; less effective at excluding species that are able to climb & jump over fences (the latter require specific designs)	Solid barrier; cost effective in the long term	Expensive to install and maintain; digging animals may be persecuted; limits movement of non-target species; may have negative ecological effects on the ecosystem	Australia; South Africa; US	Communal rangelands and large scale farms; certain adaptations can be made in fences to exclude damage-causing predators but allow certain other species to pass through	Y	Y	Y	
	Night enclosures	Mobile kraals or permanent enclosures to protect livestock at night	Highly effective at limiting predation from a variety of carnivore species	Inexpensive to set up	Intensive management; fixed kraal site increase risk of erosion, trampling and overgrazing; increased risk of disease; high parasite load; rapid spreading of disease	Botswana; Kenya South Africa; Zimbabwe	Likely to be effective on most farms, but it may be less practical and more expensive to implement in extensive farming areas	Y	Y	Y	
	Seasonal enclosures	Lambing occurs in sheds or "lambing camps", i.e. smaller camps close to homestead during lambing season	Highly effective to protect young, vulnerable stock	Protect stock against predation during their most vulnerable period (i.e. lambing period)	Expensive; intensive management (especially on large scale farms)	South Africa; US	Most applicable on small stock farms, although its cost-effectiveness may limit its use	Y	Y	Y	
	Rotational/Selective grazing	Smaller camp system, keeping ewes & lambs closer to homestead; keeping livestock away from high risk areas	Potentially moderate to high	Inexpensive	Intensive management & labour; moving stock continually may increase stress levels	South Africa; US; Zimbabwe	Likely to be effective on most farms; may be less practical and more expensive to implement in extensive farming areas	Y	Y	Y	
	Timing of breeding	Ensuring livestock lambing/calving asynchronous with predator breeding; predation often peaks during the lambing or calving seasons	Potentially effective in decreasing predation on lambs/calves	Higher lambing/calving success, reduces the risk of predation on young stock; low cost manipulation	Need to be monitored; very intensive; not effective for predators that breed aseasonally; biological and grazing limitations	South Africa; US	Small to medium sized farms, although its feasibility could be limited by various factors	Y	Y	Y	

Table 6.1. continued...

Response strategy ^a	Method	Description	Effectiveness ^b	Pros ^c	Cons ^c	Countries practiced/ studied ^d	Application for SA			Available information ^e	
							PR	SC	A		
Husbandry practices cont...	Livestock breed selection	Some livestock breeds are less vulnerable to predation	Unknown	Long term solution if breed has effective predator defence	Less viable under conditions that better suit only certain species; the market price of certain breeds could make them economically less viable; predators may learn to overcome defences	South Africa	Small to medium sized farms	Y	Y	Y	Y
		Mixed herds (e.g. sheep and cattle) provides protection for smaller livestock	Effectively reduced coyote predation on sheep but not goats in the US	Cattle act as guards for sheep if they have bonded; low cost and diversifies produce	If cattle and small sheep don't bond, there is no advantage; veld may not suit livestock types or different grazing needs	US	Small stock farms, although it would be limited by livestock breed and grazing availability	Y	N	Y	Y
	Sanitation	Regular carcass removal & destruction	Effective to reduce the severity of predation, presumably because the densities of predators decrease because food availability decreases	Simple to implement; reduces total food available to predators and scavengers; prevents further habituation to "unnatural" prey (e.g. "introducing" livestock as prey)	Labour intensive and difficult to locate carcasses on large farms	US	Most practical to implement on small to medium size farms; may be limited in situations where the damage-causing species is not usually a scavenger	Y	N	N	N
		Conditioned Taste Aversion (CTA)	Animals learn to associate food with illness and subsequently avoid it	Generally ineffective; predators develop an aversion against the baits but continue to kill livestock; predators able to recognise the taste of the emetic	Could potentially repel target individuals	UK; US	All farms, although it is unlikely to be effective and practical in South Africa	Y	N	N	Y
Aversive Deterrents/Secondary Repellents	Bio-fences	Strategic placement of scent marks or sounds that initiate the presence of conspecifics or other competitors in an area	Deterred African wild dogs and wolves but not coyotes; unknown if it decreases livestock predation	Easily applied; non-lethal; inexpensive	May require multiple applications in one year; short term effectiveness	South Africa; US	Could be effective for highly territorial species, although the method still need extensive testing	Y	Y	N	N

^a see "Predation management methods" for a description; ^b effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; ^c including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; ^d examples based on the literature included in "Predation management methods"; ^e type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

	Shock collars	A collar with two prongs which administer a shock when animal approaches a designated area/target	Effective for coyotes under experimental conditions in US	Very targeted	Expensive and impractical to implement and maintain for widespread and abundant predators; limited by battery life animals will constantly test boundaries	US	All farms; although it is unlikely to prove a practical and cost-effective method under South African conditions; could be useful for endangered or threatened predator species	Y	Y	Y
	Electric fencing	Any stock proof fencing with electrified wires, which administers a non-lethal shock; or electrification of an existing predator proof fence	Increased effectiveness compared to normal fencing, because predators avoid the risk of being shocked	Long term effectiveness to exclude predators; solid barrier; long-term cost-effectiveness	Expensive to install and maintain; limits movement of non-target species; lethal for select wildlife (e.g. tortoises)	Australia; Japan; South Africa; US	All farms, although its costs and maintenance may affect its feasibility in larger areas; more suited to small to medium sized farms	Y	Y	Y
Provisioning	Supplemental feeding	Provisioning predators with alternative food to livestock	Potentially high	Initially quite effective	Might increase condition and hence fecundity of predators; may collapse territorial behaviour and increase predator densities	Europe; North America; South Africa	Can be used in addition to other techniques; certain predators may only take natural food (i.e. dog pellets) for short periods	Y	N	Y
	Translocation	Predator is removed from area where livestock losses occur	Method is generally only effective when the predator can be relocated to an area with a relatively low density of conspecifics and where livestock is absent	Immediate reprieve if damage-causing animal is removed	Expensive; vacant territory quickly filled; for social species the entire group needs to be removed; could be difficult to find a suitable release site	Botswana; Canada; Namibia; South Africa	Likely to only be feasible for protected species that occur at low densities; only where a suitable release site can be located	Y	Y	N
Non-lethal population control	Fertility control	The reproductive potential of an animal is eliminated or reduced through surgery or injection	Successfully reduced coyote predation on small stock in the US	Slow population growth; territorial animal(s) not removed	Time consuming; costly because all individuals in an area must be targeted; would require the capturing and sterilization of or the application of contraceptives to all adults of a specific sex within a population	South Africa; US	All farms, although it is unlikely to prove a practical and cost-effective method under South African conditions	Y	N	Y
	Compensation	Paying farmers for livestock losses	If well administered and measures are in place to monitor and confirm claims of predation, the method may limit persecution of damage-causing carnivore species	Reduction in retaliatory killing and more tolerance to predators; when designed and implemented correctly it may encourage better livestock management practices	Potentially expensive; open to fraudulent claims; may discourage good husbandry in some instances; difficult to monitor over extensive areas; only shifts the economic costs of livestock predation	Asia; Europe; Kenya; Pakistan; US	Communal rangelands and large scale farms; although it is unlikely to be a financially feasible and practical option where livestock predation is high	Y	N	N
Producer management	Insurance	Livestock are insured against losses	Can be implemented successfully where livestock flocks/herds are small and livestock predation is low	Increases predator tolerance and encourages farmers to mitigate against livestock predation	Potentially costly and open to fraudulent claims; difficult to monitor over extensive areas	Botswana; India	Communal rangelands and large scale farm, although it is unlikely to be a financially feasible and practical option where livestock predation is high	Y	N	Y

Table 6.1. continued...

Response strategy ^a	Method	Description	Effectiveness ^b	Pros ^c	Cons ^c	Countries practiced/ studied ^d	Application for SA			Available information ^e		
							PR	SC	A			
Lethal predator management	Producer management cont...	Financial incentives	Financial incentives motivate producers to implement or commit to certain predation management methods or to hunt certain species or to tolerate certain species	Reduction in retaliatory killing; reduction in blanket lethal control; increases predator tolerance (except when bounties are paid)	Potentially costly and open to fraudulent claims; difficult to monitor over extensive areas; only shifts the economic costs of livestock predation	Australia; Mongolia; North America; South Africa	Subsidies/Tax rebates is likely to be an effective way to motivate farmers to implement certain methods; due to a limited market for "wildlife friendly brands", it is unlikely to be economically sustainable on a large scale	Y	Y	N		
		Shooting	High powered rifle used on target species, in combination with calling or from an aircraft	Species specific; cheap; easy to implement on the individual farm level	Creates vacancies for other predators to disperse into; has to be implemented annually; generally unselective towards the damage-causing individual; older individuals may learn to avoid shooting; counterproductive and increases predator numbers	Australia; North America; Norway, South Africa	Excessive shooting may be counterproductive due to the impact of immigration and "compensatory breeding"; where 'shooting' is applied, measures should be put in place to ensure that only the damage-causing individuals are targeted	Y	Y	Y		
		Denning	Removal and or killing of young at dens	Effectively reduced coyote predation on sheep in the US	Easy to implement if den locations on a property are known	Expensive; time consuming, annual application needed; involves indiscriminate killing; possibility to activate "compensatory breeding"	South Africa; US	The method's potential ecological effects and unethical nature may limit its usefulness in South Africa	Y	Y	Y	
		Hunting dogs	Detecting, chasing, luring and killing predators with the aid of trained domestic dogs	Historical data suggest that this method was not very effective in South Africa	Can be trained to be reasonably selective	Expensive, generally non-selective, successfulness influenced by a variety of factors including seasonality, climatic conditions and topography	Botswana; Costa Rica; Kenya; North America; Philippines; Russia; Siberia; South Africa; UK	May have limited application to chase or point potential damage-causing predators; correct training may increase the method's successfulness	Y	Y	Y	
		Poisoned baits	Poisoned baiting has been shown to be successful at decreasing the populations of some predators; although there are some cases in Australia where livestock predation continued after the application of poisoned baits	Cheap; easily applied	Indiscriminate; short term success; some predators may avoid poisoned baits (bait aversion can occur)	Australia; South Africa; US	Illegal in most countries; not recommended because of its indiscriminate nature in the South African context	Y	Y	Y		

^a see "Predation management methods" for a description; ^b effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; ^c including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; ^d examples based on the literature included in "Predation management methods"; ^e type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

Lethal predator management cont...									
Coyote get- ters/M44	Poison from a cartridge discharged into face and mouth of predator when the device are triggered	Effective to capture black-backed jackal in South Africa; unknown to what extent it decreases livestock predation	More selective than baited poisoning; poison is more secured compared to baited poisoning	Traditional forms of capture are indiscriminate; younger animals; some species learn to avoid devices	Australia; South Africa; US	Traditional forms of "getters" are not recommended because of its indiscriminate nature	Y	Y	Y
Poisoned collars	Collars with pouches that contain a lethal dose of poison	Potentially high, but is extremely context specific	Most selective application of poison; selective towards predators that bite livestock in the throat area where the poison pouches are situated	Spillage can potentially kill livestock; possible negative environmental impact when scavengers feed on poisoned carcasses (dependant on the poison that is used); predators may get habituated to the collars; cost-prohibitive for extensive grazing systems	South Africa; US	Can effectively be used to target damage-causing individuals of certain species; important to use it only where and when damage has been caused; can be fitted to 10 - 20 individuals and move rest of stock to another camp; recommended for not more than seven days	Y	Y	Y
Cage traps	Baited cages for live trapping of predators	High efficacy to capture certain species; typically little success with canids	Can be effective on felines and primates; non-target species are released; easy to implement	Not always possible to know whether the specific damage-causing individual has been caught; traps need to be monitored daily	Namibia; North America; South Africa	Effective to capture certain species	Y	Y	Y
Leghold devices	Traps the foot of the predator	Effective to capture certain damage-causing species; but unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; modified traps (≈ soft traps) may cause fewer injuries; low cost	Labour intensive if traps are checked frequently; potentially unselective if poorly set; the traditional "gin" trap can cause severe injuries and is now illegal	Australia; North America; South Africa	Traditional forms of traps are not recommended because of their indiscriminate nature and because of the injuries they can cause to some species	Y	Y	Y
Foot loop traps	Traps the foot of the predator	Typically little success for capturing canids in Northern America; unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; low cost; easy to implement	Labour intensive if traps are checked frequently; potentially unselective if poorly set; can cause severe injuries if poorly set and not checked	North America; South Africa	Traditional "snares" are not recommended because of their indiscriminate nature; but may be effective for certain species, especially felids	Y	Y	N
Neck or body snares	Traps the predator around the neck or body	Neck snares are viewed as one of the most effective methods to capture canids in the US; unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; low cost; easy to implement	Labour intensive if traps are checked frequently; unselective; can cause severe injuries if poorly set and not checked	US	Not recommended without the use of a "stopper"; also indiscriminate if poorly set; not recommended for felids	Y	Y	N
Killer trap	Placed at an opening under a fence; traps on the head or body of the predator	Unknown	Cheap; easily applied	Indiscriminate	South Africa	Not recommended because of its indiscriminate nature	N	N	Y

Disruptive deterrents

Fladry

Fladry consists of brightly-coloured pieces of cloth tied at specific intervals along a line, and was originally used to direct the movements of wolves *Canis lupus* (Okarma & Jędrzejewski, 1997). This non-lethal method is easy to implement and, apart from its installation, may require minimal logistics (Young, Miller & Essex, 2015). It has been shown to successfully deter captive wolves and coyotes *Canis latrans* for short periods (\approx ca. 1 day) from areas where food is placed (Musiani & Visalberghi, 2001; Mettler & Shivik, 2007). Under field conditions, it was found to successfully deter wolves from various livestock farms in the US (Musiani *et al.*, 2003; Davidson-Nelson & Geihring, 2010), but not coyotes (Davidson-Nelson & Geihring, 2010). Musiani *et al.* (2003) found that the usefulness of fladry may, however, be restricted to a finite period (1-60 days). Furthermore, Mettler & Shivik (2007) found that fladry was less successful against dominant predator individuals that generally take more risks when it comes to livestock predation.

Electrified fladry differs from normal fladry in that the fladry line consists of an electrified poly-wire. It is more difficult to install than normal fladry and it is also more expensive (Lance, 2009). It may, however, be more successful at deterring predators than normal fladry. For example, Lance, Breck, Sime, Callahan & Shivik (2010) found that under test conditions, electric fladry deterred wolves for longer (\approx 2 to 10 times) compared to normal fladry. In addition, Gehring *et al.* (2006) found that electrified fladry deterred wolves from livestock farms in Michigan, US for up to 90 days.

To date, fladry has not been tested in South Africa, but various farmers do apply the concept (e.g. hanging brightly coloured containers or flags on fence lines – N. Viljoen, 2017, pers. comm.). Although fladry might successfully deter certain predators in South Africa, it is likely that the method will only be effective in the short term because of habituation by the target species. Electrified fladry may have a longer lasting effect, presumably because of its aversive properties. Overall, the cost-effectiveness of and the practicality of implementing fladry may be limiting factors for its successful implementation, especially on extensive livestock farms.

Human herders

With the exception of isolated cases where a predator is killed by a herder, human herders are considered a non-lethal predation management technique. While a trend away from human herders started to occur over 100 years ago in Australia (B. Allen, 2017, pers. comm.) and after the mid-1990's in the US (Hygnstrom, Timm & Larson, 1994), the method is still widely used in Africa and Europe (Kaczensky, 1999; Ogada, Woodroffe, Oguge & Frank, 2003; Patterson, Kasiki, Selempo & Kays, 2004). In the latter settings, livestock herds/flocks are generally kept in relatively small areas and are enclosed at night. McAdoo & Glimp (2000) hypothesised that herders will likely be a successful predation management method in most cases because they can provide a reliable deterrent. Herders are in a good position to make field observations on the condition of fences, presence of predators and the condition of the veld which can be of value for any adaptive management used by the farmer (Palmer, Conover & Frey, 2010; Hawkins, 2012) and employing herders may provide for job creation through new or existing government supported initiatives (e.g. Jobsfund; Extended Public Works Program). However, certain predators may become habituated to the presence of a herder and adapt their activity to attack stock when they are most vulnerable (Du Plessis, 2013; Fehlmann, O'Riain, Kerr-Smith & King, 2017). Herders may also be less effective when flock or herd size increases, when flocks or herds are widely dispersed, and as grazing area (\approx farm or camp size) increases (Shivik, 2004). The latter issues could be less problematic when herders also use working dogs to help guard their stock.

In South Africa, herders are successfully used by most subsistence farmers (Webb & Mamabolo, 2004; Constant, Bell & Hill, 2015; Hawkins & Muller, 2017); presumably most of these farmers now also graze their stock in relatively small areas. While some commercial small stock farmers in South Africa employ herders to guard their stock (Van Niekerk, 2010), and anecdotal reports point towards them being effective (Viljoen, 2015), there is no published scientific evidence available to confirm the effectiveness of the method. In addition, it is speculated that herders may not be cost-effective in the commercial context in South Africa because of labour costs (Viljoen, 2015). This, and the extensive nature of many commercial livestock farms in South Africa, will

likely make herders a less viable option. More recently, modern shepherds (with and without guard dogs) were trialled in Namaqualand using a Before-After-Control-Impact design and the results of this study will be important for assessing the prospects of this method on small livestock farms in South Africa (C. Teichman, 2017, unpublished data).

Guarding animals

A variety of animals have been used around the world to guard cattle, sheep, and goats from predators. The best-known of these are: dogs *Canis lupus familiaris*, donkeys *Equus asinus*, llamas *Lama glama*, and alpacas *Vicugna pacos* (Hygnstrom et al., 1994; Rigg, 2001; Jenkins, 2003;

Weise, Vidu & Fernandez-Armesto, in Press). Although it is the larger dog breeds that have traditionally been developed as guarding animals (Andelt, 1992; Landry, 1999), there are instances where other smaller, mixed breed dogs have also been successfully used in this role (e.g. Coppinger & Coppinger, 2001; Gonzales et al., 2012; Horgan, 2015). The most commonly used, and hence most well-studied, guarding animal is the livestock guarding dog (LGD) (Rigg, 2001; Gehring, VerCauteren & Landry, 2010; van Bommel & Johnson, 2012; Allen, Stewart-Moore, Byrne & Allen, 2016). A variety of specifically bred LGDs are available (Rigg, 2001), although some local, mixed breeds are also employed in some areas (Figure 6.1).



Figure 6.1. Examples of livestock guarding dogs. Anatolian Shepherd or Kangal dog (left) and mixed-breed livestock guarding dogs used in Namibia (right). Photos: Gail Potgieter.

In Namibia and Botswana, LGDs have been used successfully against most of the common predators that occur on farmlands in these countries, including black-backed jackals *Canis mesomelas*, caracals *Caracal caracal*, cheetahs *Acinonyx jubatus*, leopards *Panthera pardus* and chacma baboons *Papio ursinus* (Marker, Dickman & MacDonald, 2005; Horgan, 2015; Potgieter, Kerley & Marker, 2016). In Botswana, relatively small, mixed-breed dogs are effective at reducing livestock losses, probably by disrupting predators from the normal hunting sequence through barking (Horgan, 2015). Similarly, large purebred dogs in Namibia appear to non-lethally prevent cheetah and leopard predation, and are known to confront and kill black-backed jackals and caracals (Potgieter et al., 2016).

LGDs in Namibia and Botswana are usually used to guard small stock that are kraaled (\approx corralled) at night, and human herders are frequently employed to keep the livestock together (Potgieter, Marker, Avenant & Kerley, 2013; Horgan, 2015). In the absence of herders, the sheep or goats generally stay together as a flock, although some farmers report that their guarding dogs also help keep the flock together (Horgan, 2015). In Australia, some farmers use LGDs on large properties (> 10,000 ha) under an extensive management system where the livestock are not herded and the dogs are allowed to roam freely throughout the property (van Bommel & Johnson, 2012). Under these circumstances, it appears that LGDs are most effective when guarding 100 or fewer head of livestock per dog (van Bommel & Johnson,

2012). One guarding dog puppy should be introduced to the livestock at a time, as puppies introduced at the same time tend to increase problems of playing roughly with the livestock. However, once an adult dog has been established with the livestock, introducing a new puppy can be easier as the older dog trains the younger one (van Bommel, 2010). In this way, a large group of LGDs can be used to protect extensively managed livestock over a large area (van Bommel & Johnson, 2012). This is achieved through direct LGD protection or guarding of sheep, not through indirect exclusion of predators from areas where sheep are grazed (Allen *et al.*, 2016).

Hansen & Bakken (1999), Gingold, Yom-Tov, Kronfeld-Schor & Geffen (2009) and Potgieter *et al.* (2016) found that LGDs may have a negative impact on the environment by chasing wild ungulate species or by killing intruding wildlife that pose no threat to or competition with livestock for grazing. Unless there are vulnerable or protected species in the area where LGDs are employed, the advantages associated with this method will likely outweigh the potential negative impacts. Timm & Schmitz (1989) also reported cases where LGDs killed livestock. The latter behaviour is more likely where more than one LGD is used to protect a flock or herd, and is related to play behaviour rather than aggression (Snow, 2008). It is, however, possible to limit livestock and wildlife killing behaviour in most LGDs with suitable training and care (Dawydiak & Sims, 2004; Potgieter *et al.*, 2016).

The use of LGDs is considered an ethically acceptable predation management method in South Africa (Smuts, 2008) and there is evidence confirming that LGDs can be effective under South African farming conditions. In a study by Leijenaar, Cilliers & Whitehouse-Tedd (2015), where LGDs were placed on 135 livestock farms throughout the North West and Limpopo provinces, farmers reported significant decreases in livestock predation across various farm types, including small stock, cattle and game farms after LGDs were introduced. In addition, an unpublished study by Herselman (2006) demonstrated that LGDs successfully reduced predation on 43 small stock farms across South Africa. McManus *et al.* (2015) also found that LGDs may be relatively cost-effective, compared to lethal alternatives (in this instance shooting, foothold traps and coyote-getters). It is widely accepted that the success of any LGD programme is

intimately linked to the selection of a breed and individual dog for a particular area and livestock, the quality of the training before deployment, and their care/husbandry while they are in the field (Dawydiak & Sims, 2004; van Bommel, 2010).

When utilised correctly, alpacas, donkeys, and llamas may deter a variety of smaller carnivores in different settings (Jenkins, 2003). Advantages of alternative guarding animals compared to LGDs include reduced bonding time with livestock (4-6 weeks, compared to about 6 months for LGDs) (Jenkins, 2003) and less care. Donkeys, alpacas and llamas have been used in the US and Australia with flocks and herds of between 200-300 head of small stock, on small or medium-sized properties (between 100-400 ha) (Walton & Field, 1989; Andelt, 1992; Jenkins, 2003). Farmers in North America and Australia report that donkeys, llamas and alpacas are less effective when the livestock spread out over large properties with an undulating landscape (Jenkins, 2003). In Australia, they are also mostly effective against foxes, but not dingoes (B. Allen, 2017, pers. comm.). However, donkeys used in Namibia effectively reduced livestock losses on extensive farms (5 000 to 8 000 ha) with cattle herds of 70-80 head, under which circumstances they may also keep the cattle together in one herd (Weise *et al.*, in Press).

Groups of donkeys or llamas tend to stay closer to their conspecifics than with the livestock they are meant to guard (Jenkins, 2003; Weise *et al.*, in Press). However, introducing a female donkey (jenny) and her foal to livestock can be highly effective, as jenny's are especially protective of their young (Bourne, 1994; Jenkins, 2003). The main behavioural problems associated with these alternative guardian animals are: aggression towards new-borns, mounting ewes in the flock and aggression towards people (Jenkins, 2003; Weise *et al.*, in Press). These issues can be resolved or minimised by separating the guarding animal from the flock during lambing season (although this may be counterproductive as this is often when predation risks are the highest), not using intact males as guardians, and maintaining regular human contact with the guarding animal (Weise *et al.*, in Press).

Like LGDs, alternative guarding animals have been proposed as an ethically acceptable predation management method for South African farmers (Smuts,

2008). There is, however, very limited scientific information on alternative guarding animals in South Africa. There is an unconfirmed report of alpacas deterring chacma baboons from attacking stock (Lindhorst, 2000). In addition, according to Schepers (2016), South African game farmers list alternative guarding animals as one of the predation management methods that many prefer to use, this indicates that alternative guarding animals are at least perceived to be successful. McManus *et al.* (2015) tested the use of alpacas on one farm as part of a larger study on non-lethal predation management methods, and it appears that this was successful, although the authors did not present the results for alpacas separately to the other methods they tested, and there was no replication of the study. Similar to LGDs, it is important to follow correct procedures wherein alternative guarding animals are utilised to ensure best results (e.g. Jenkins, 2003; Weise *et al.*, in Press).

Cellular communications technology

Cellular communications technology can be incorporated into an animal collar which sends a radio signal to the farmer when abnormal behaviour (e.g. running) is detected within a livestock herd (Lotter, 2006; Viljoen, 2015; PMF, 2016) or when a collared predator cross a predetermined boundary (also see Box 6.1). The farmer can then investigate and respond accordingly. A disadvantage of cellular communications technology, however, is that it is limited by cellular reception nodes in many of the farming areas in South Africa. The use of satellite transmission technology could overcome the issue of poor reception, but the relatively high cost of satellite collars will likely prohibit their use. Cellular communications technology may also be less practical to use on extensive farming operations where it is not possible to reach the livestock quickly. Also, the false alarms attributed to livestock running for reasons other than predators may reduce farmer response rates to actual predation events. This can be mitigated to an extent by linking areas where animals are running to other elements like water and food sources for livestock and fence lines.

Disruptive stimuli

Disruptive stimuli can be applied through devices (\approx fear inducing or frightening devices) that generate

noises, lights, reflections or smells (Pfeifer & Goos, 1982; Bomford & O'Brien, 1990; Hygnstrom *et al.*, 1994; Shivik & Martin, 2000; Shivik *et al.*, 2003; VerCauteren, Lavelle & Moyles, 2003; Figure 6.2). Bell collars are primarily applied as a disruptive stimulus, although they may also act as a protection collar (see "Protection collars"). Breck, Williamson, Niemeyer & Shivik (2002) and Darrow & Shivik (2009) noted that lights and noises were effective at deterring coyotes and wolves under test conditions in the US. In addition, Linhart, Dasch, Johnson, Roberts & Packham (1992) recorded a decrease of ca. 60% in sheep losses to coyotes when a disruptive device that produced a combination of lights and noises was used on livestock farms in Colorado and Wyoming, US. Similarly, VerCauteren *et al.* (2003) recorded no coyote damage over a period of two months on a sheep farm in Wyoming, US after an acoustic device was employed.



Figure 6.2. Solar powered acoustic and light generating device (\approx frightening device) set on a livestock farm in South Africa. Photo: Niel Viljoen.

Despite these apparent successes, the effectiveness of the various disruptive devices are short-lived because carnivores habituate rapidly to them (Smith, Linnell, Odden & Swenson, 2000; Shivik *et al.*, 2003). Various studies that tested the use of different disruptive devices to deter primates found that effectiveness is limited to a finite period because primates are easily habituated (Sitati & Walpole, 2006; Kaplan, 2013; Kaplan & O'Riain, 2015). Rotating deterrent strategies (multiple stimuli used in various combinations at irregular intervals – Koehler,

Marsh & Salmon, 1990) or developing deterrents according to the target species' biology, i.e. using a predator model or playing back target species' distress calls (Belant, Seamans & Tyson, 1998), are two ways to delay habituation. However, most frightening devices are only effective in relatively small areas over relatively small timeframes, and the implementation and running costs can be high (Gilsdorf, Hygnstrom & VerCauteren, 2002).

Despite the use of a variety of disruptive devices by many South African livestock farmers (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016), their effectiveness to manage livestock predation has not been tested scientifically. However, an emerging concept which integrates a combination of disruptive stimuli to form a virtual fence against predators could prove to be effective in the long term (see Box 6.1).

Box 6.1 Baboon management and virtual fencing

Baboons are not traditionally considered to be serious predators of livestock. However, in communal lands in Zimbabwe, a household survey by Butler (2000) reported that baboons were responsible for more losses than larger predators like lions and leopards (mainly young goats targeted by adult male baboons), although economic costs were still largely determined by lion predation which targeted more valuable livestock. It has also become increasingly evident in recent years that, on a local scale, baboons could become additional predators of small stock in areas like the Karoo, especially during droughts (Tafari & O'Riain, 2017; Chapter 9). While no mitigation measures exist to reduce baboon predatory behaviour *per se*, various management strategies for mitigating baboon raiding behaviour have been proposed and tested in both rural and urban environments throughout Africa (Naughton-Treves, Treves, Chapman & Wrangham, 1998; Hill & Wallace, 2012; McGuinness & Taylor, 2014; Richardson, 2016) and Saudi Arabia (Biquand, Boug, Biquand-Guyot & Gauthier, 1994). Management strategies are generally tailored to local problems and seldom achieve long-term success because baboons readily habituate to deterrents and overcome physical barriers (Kaplan & O'Riain, 2015; Howlett & Hill, 2016; Fehlmann *et al.* 2017).

Recently, however, successes have been achieved in baboon management in and around the urban areas of Cape Town (Richardson, 2016; Fehlmann *et al.*, 2017; Richardson *et al.*, 2017). Over the past five years, teams of rangers, using aversive tools like paintball markers and bearbangers (\approx .22-calibre blank powered flare gun that fires cartridges that travel 20 m then explode with a bang), have kept baboons out of the urban areas of Cape Town for over 98.5% of the time (Richardson *et al.*, 2017). Baboons are able to learn raiding (Strum, 2010; Richardson *et al.*, 2017) and predatory (Strum, 1981) behaviours from other troop members, so sometimes lethal management (with strict protocol conditions – CapeNature, 2011) is required to break this training cycle. A similar combination of non-lethal deterrents with selective removal of problem individuals could be tested on South African farms where baboons are killing livestock, if the offending individuals can be identified. However, a promising new and less labour intensive non-lethal strategy that can be tested in a livestock farming context, is virtual fencing (Richardson *et al.*, 2017).

A virtual fence can be defined as a non-physical structure serving as a barrier or boundary (Umstatter, 2011). It can therefore be likened to a territorial boundary which may be advertised in a variety of ways including loud calls, scent marks and visual cues (Hediger, 1949; Mech, 1970; Richardson, 1993). These advertisements are designed to keep intruders away through fear of retribution (physical punishment

or death), if caught (Hediger, 1949; Richardson, 1993). In both instances, the mechanism by which the boundary is maintained, is embedded in the “landscape of fear” theory (Laundre, Hernandez & Ripple, 2010). Studies of prey responses to different predation risks have shown that most individuals realize those risks and adjust their behaviour to reduce them, even at the cost of losing feeding opportunities (Caro, 2005; Landré *et al.*, 2010, Crowsight *et al.*, 2013). Furthermore, behavioural responses should vary depending on how the level of risk varies in time and space (Crowsight *et al.*, 2013). If the virtual fence boundary is well defined, i.e. spatially predictable, an animal will know it is approaching the boundary (as it would a territorial boundary) and therefore be wary. However, if the signal is temporally unpredictable, the animal will not know when the retribution is likely to happen. This will create a high level of uncertainty which will compound the level of stress (and fear) (Crowsight *et al.*, 2013; Richardson *et al.*, 2017). Although the timing of the activation of the virtual fence must be unpredictable, its activation must remain a certainty. An intruder should never be allowed to intrude without being punished (Richardson, 1993). Similarly, although location of the fence line should be predictable, the position of the “attack” along the fence line should remain unpredictable, thus further enhancing the fear factor.

Species that have close-knit social structures are ideal for virtual fence designs, because a single GPS-collar on a high-ranking individual represents the larger family group’s movement. Virtual fences are therefore best suited to slowly reproducing, long-lived and group-living species with overlapping generations (Jachowski, Slotow & Millspaugh, 2014). Baboons are therefore ideally suited to management by virtual fencing. In view of this, a 2 km virtual fence (between the Steenbras Dam and the Indian Ocean) was designed to keep baboons in the Steenbras Nature Reserve and prevent them from raiding Gordon’s Bay in the Western Cape Province (Richardson *et al.*, 2017). A landscape of fear was generated by playing the calls of natural predators, alarm calls, the sounds of prey being killed, or predators fighting over their kills. In addition, loud scary bangs or whistles were produced by means of “bearbanger” pyrotechnics. The high variety of stimuli was designed to add to the unpredictability of the system, and therefore to reduce the chances of habituation (Flower, Gribble & Ridley, 2014).

All these stimuli were produced by remotely activated action stations, each of which contained two high ampere speakers and a double-barrelled bearbanger (Richardson *et al.*, 2017). The troop’s position was determined on a daily basis via GPS radio telemetry. When the troop was more than a day’s foraging distance from the virtual fence it could be ignored for the rest of the day. However, if the troop was closer, it was monitored remotely throughout the day. In total, three baboons were radio collared, and they transmitted readings once every 10 or 30 minutes. If the troop approached to within 500 m of the virtual fence, then a team of rangers was sent out to observe from a distance, and unobtrusively deploy the action stations (Figure 6.3) if the baboons were continuing to approach. Five action stations were placed about 75 m apart and out of sight, but directly in the path of the baboons. If the troop advanced to within 50 – 70 m of the virtual fence, a selection of deterrent calls was played before firing off 1 – 3 bearbangers. All activations of the virtual fence were successful in repelling the baboons. During the first eight months of implementation, the virtual fence needed to be activated 13 times, but only three times in the following eight months (Figure 6.4; last activation in April 2017). This suggests that the virtual fence had created an effective landscape of fear (Richardson *et al.*, 2017). After being first activated in January 2016, the baboon troop tried to cross the fence another 15 times but was effectively repelled each time. The virtual fence was therefore 100% effective in keeping the troop out of Gordon’s Bay

(Richardson *et al.*, 2017). At this stage, there is no evidence to suggest that the baboons are becoming habituated to the virtual fence. This is ascribed to the scariness and variety of the stimuli produced.



Figure 6.3. Virtual fence, Mark I-model, remote controlled action station. Note the two double-barrelled bearbanger guns, loaded with banger (red) and whistler (green) flares, and one high ampere speaker. The Mark III-model action stations are fully waterproof and have two speakers and only one gun. Photo: Phillip Richardson.

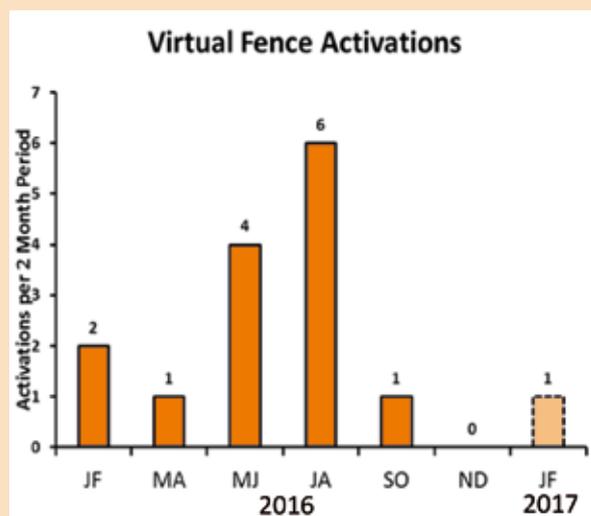


Figure 6.4. Number of virtual fence activations per two month period from January & February 2016 – January & February 2017. Dotted line indicates activation for a solitary male in January 2017 (from Richardson *et al.*, 2017).

Virtual fencing is an innovative, new tool that has several management benefits over traditional barrier fences (Jachowski, *et al.* 2014), and is not physically harmful to wildlife. In Australia and the US,

conservationists are pushing for more widespread development of virtual fencing, because of its many potential ecological and economic benefits (Umstatter, 2011). Non-human primates are renowned for habituating rapidly to deterrent stimuli (Kaplan & O’Riain, 2015). Nevertheless, after an 18 month trial, the results from Gordon’s Bay suggest that virtual fencing is another tool that can potentially be utilised in the protection of livestock against baboons and other predators. However, careful attention must be paid towards utilizing a wide variety of stimuli, whose activation must be highly unpredictable.

Protection collars

Protection collars are plastic or metal collars that protect livestock, most commonly small stock, against neck and throat bites (King, 2006; Snow, 2008). Such collars work on the assumption that when a predator is not able to bite through the collar, it will eventually be discouraged from attacking livestock. Bell and poison collars can also be classified as protection collars, although they are primarily implemented for other purposes (see “Disruptive stimuli” and “Poisons”). There is a lack of scientific evidence on the effectiveness of protection collars to deter livestock predation. Steinset, Fremming & Wabakken (1996) found no significant effect of protection collars against lynx *Lynx lynx* and wolverine *Gulo gulo* predation on sheep lambs in Norway. In addition, some predators are capable of biting through the collars (Snow, 2008) and they are only effective against throat bites (Conover, 2002). In South Africa, questionnaire studies show that livestock farmers often report the use of protection collars (Van Niekerk, 2010; Badenhorst, 2014). However, it is also often alleged that certain South African predators, especially black-backed jackals, become habituated to protection collars and attack the hindquarters when they are unable to inflict a throat bite (Todd, Milton, Dean, Carrick & Meyer, 2009).

Husbandry practices

Fencing

Fencing is generally the first line of defence that is employed to exclude predators from certain areas (Sillero-Zubiri & Switzer, 2004; Kolowski & Holekamp, 2006). Extensive fencing is used effectively in Australia (\approx dingo barrier fence) to exclude dingoes from small-stock producing areas (Newsome, Catling, Cooke & Smyth, 2001; Allen & Fleming, 2004; Clark, Clark &

Allen, in Press). Currently, fencing is one of the more preferred non-lethal predation management methods on livestock farms throughout South Africa (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016). South African farmers either enclose their entire property, certain areas of their farms (e.g. habitats that are believed to be frequented by predators), or smaller camps for lambing purposes.

For a fence to successfully exclude a predator it is important that it is designed according to the size, strength, and physical agility of the species to be excluded (Fitzwater, 1972; Eklund *et al.*, 2017). In South Africa, it is widely assumed that well-maintained “jackal proof” fencing (wire mesh or closely-spaced wire strand fences, with a minimum height of 1,3 m; Figure 6.5, see following page) is effective at excluding most canids (most notably black-backed jackals – Davies-Mostert, Hodgkinson, Komen & Snow, 2007; Smuts, 2008; Viljoen, 2015; PMF, 2016). However, “jackal proof” fencing is less effective at excluding species that are able to climb or jump over fences (Davies-Mostert *et al.*, 2007; PMF, 2016). Despite the prevalence of fencing to deter predators, there have been no scientific studies on their effectiveness at excluding damage-causing predators, or reducing their impacts, in South Africa.

Fencing may be a cost-effective, long-term intervention in South Africa, especially where losses due to predation are high. Nass & Theade (1988) and Perkins (2013), in studies in the US and Australia, respectively, calculated that although the initial input cost of fencing is high, the financial benefits, due to decreased livestock predation and the relatively low maintenance costs of fencing, outweigh the input costs in the long-run in both countries. Maintenance costs in most of South Africa may be higher as the large number of species (e.g. warthog *Phacochoerus africanus*, armadillo *Orycteropus afer*



Figure 6.5. Properly maintained jackal-proof fencing is generally effective to exclude most canid species in South Africa. Photo: Niel Viljoen.

and porcupine *Hystrix africaustralis*) adept at digging under fences would require frequent and extensive maintenance. There are also negative ecological or environmental impacts associated with fencing. Farmers may lethally control digging species resulting in higher levels of by-catch (Beinart, 1998). This could be countered by the installation of semi-permeable fences (i.e. fences with specially designed gaps installed at intervals) that can allow digging species through and still exclude predators (Schumann, Schumann, Dickman, Watson & Marker, 2006; Weise, Wessels, Munro & Solberg, 2011). However, it is possible that predators may habituate to these fences in the long term.

Fences also have negative ecological impacts by fragmenting the landscape and preventing dispersal of non-target wildlife that perform important ecological roles. There may also be other unintended consequences. For example, in Australia, predators were excluded by fencing from large parts of the country (Newsome *et al.*, 2001; Letnic *et al.*, 2011). Where dingoes were rare, herbivore and fox numbers were higher, which the authors attributed to the meso-predator release hypothesis (\approx smaller predator numbers increase in the absence of larger competing predators) to explain their results (Newsome *et al.*, 2001; Letnic *et al.*, 2011; but see also Allen *et al.*, 2013a). It is possible that similar impacts may occur under South African conditions where large areas are fenced (see Chapter 8). However, true meso-predator release has, to date, not been formally

demonstrated in any Australian or African ecosystem (Allen *et al.*, 2013a; Allen *et al.*, 2017).

Night/Seasonal enclosures

Night enclosures (\approx kraals/corrals/bomas) are used to protect livestock at night and seasonal enclosures (\approx shed-lambing or “lambing-camps”) are employed to protect vulnerable livestock during the early parts of the lambing or calving season (Knowlton, Gese & Jaeger, 1999; Gese, 2003). Correctly designed kraals, taking into account the predator species against which the livestock are protected (e.g. Howlett & Hill, 2016), are generally seen as effective at limiting predation (Robel, Dayton, Henderson, Meduna & Spaeth, 1981). Kraals have been and are still widely used by subsistence farmers to protect their stock at night (Ogada *et al.*, 2003), including in South Africa (Webb & Mamabolo, 2004; Constant *et al.*, 2015; Hawkins & Muller, 2017). Many commercial cattle and small stock farmers in South Africa also indicate that they employ kraaling (Van Niekerk, 2010; Badenhorst, 2014). It is, however, unknown to what extent kraaling is effective in South Africa as a predation management method. This is an intensive practice with high labour costs (Shivik, 2004). It is also generally less practical as the size of the herd and grazing area increases (Shivik, 2004; Van Niekerk, 2010). Furthermore, kraaling may also negatively affect grazing condition (due to overgrazing, localized concentrations of livestock trampling and increasing nutrient loads through faecal matter), livestock health (diseases may be more easily transmitted under kraaling conditions) and the quality of wool (Snow, 2008). Overgrazing and trampling can be ameliorated by mobile kraaling (e.g. Riginos *et al.*, 2012), but this would require additional labour and expense. Literature from the US suggests that a similar approach to kraaling (lamb shedding) can improve productivity by up to 200%, but it is costly to implement (McAdoo & Glimp, 2000). Overall, the practicalities of mass kraaling on extensive farms, and where large herds are farmed, remain a significant limitation in many parts of South Africa.

Rotational or selective grazing

Livestock predation is often spatially confined and, in such instances, predation could be reduced by excluding livestock from these “hotspots” (McAdoo & Glimp, 2000; Shivik, 2004). Minnie, Boshoff & Kerley

(2015) reported that the majority of livestock farmers bordering the Baviaanskloof Mega-Reserve, Eastern Cape Province indicated that they withdrew their stock from the areas bordering the reserve because of the perceived predation risk. However, the extent to which this strategy decreased predation was not described (Minnie *et al.*, 2015). Furthermore, repeatedly moving livestock can cause stress to the animals and is therefore not always an acceptable approach (Van Niekerk, 2010).

Timing of breeding

Livestock predation often peaks during the lambing or calving seasons or during drier periods when natural prey availability is limited (Tafari & O’Riain, 2017). In such instances, a shift in lambing or calving season so that it does not coincide with either of these events could result in lower livestock predation (Hygnstrom *et al.*, 1994; McAdoo & Glimp, 2000; Snow 2008). Livestock species exhibit seasonal breeding characteristics, but because they are intensively managed, livestock producers have the ability to manipulate the timing of breeding by using contraceptives and/or restricting physical contact between males and females (Gordon, 2017). Some livestock producers in South Africa use this method and indicate that it is effective (Van Niekerk, 2010; PMF, 2016), but it remains to be subjected to formal scientific experimentation. Importantly, as the lambing season is generally the time when most small stock are lost (e.g. Avenant & Nel, 2002; Pohl, 2015), it may be prudent for farmers in a specific region to try synchronise their lambing period as closely as possible to limit the total number of losses in the area. Shifting the timing of breeding may, however, incur undesirable nutritional or productivity costs.

Altering herd composition

The implementation of flocks (mixing sheep or goat flocks and cattle herds) has been shown to effectively reduce coyote predation on sheep but not goats in the US (Hulet, Anderson, Smith & Shupe, 1987; Hulet *et al.*, 1989; Anderson, 1998). McAdoo & Glimp (2000) and Shivik (2004) highlighted various shortcomings with this approach suggesting that it can be a very time-consuming and strenuous process, especially when trying to bond different livestock species. In some areas it can be difficult, or even impossible, to introduce

cattle or small livestock because of grazing conditions or topography. Further, where there are larger predators that have the ability to kill cattle, flerding will not be effective. Moreover, predators may become habituated to the presence of the larger livestock (McAdoo & Glimp, 2000; Shivik, 2004). It is sometimes possible to switch to certain livestock breeds that are less susceptible to predation (Greentree, Saunders, Mcleod & Hone, 2000; White, Groves, Savery, Conington & Hutchings, 2000). However, such switching may not always be economically or environmentally viable (Du Plessis, 2013).

Sanitation

There is some scientific evidence to show that carcass removal around livestock operations may reduce the severity of livestock predation (Robel *et al.*, 1981; Hygnstrom *et al.*, 1994). Presumably this is because the removal of potential food resources (\approx animal carcasses), reduces the overall food available to predators in an area (Shivik, 2004). Furthermore, although virtually nothing has been published on this, the removal of livestock carcasses may limit a predator’s chances to “learn” to prey on livestock (Avenant, 1993; Avenant & Nel, 2002). There may, however, be constraints for large scale operations with farmers being unable to remove all carcasses (Shivik, 2004). Furthermore, carcass removal will be less effective when the predators implicated are not typically scavengers.

Grazing and natural prey management

Rodents and small game comprise the bulk of the diets of most livestock predators in South Africa (see Chapter 7), as well as in other countries (e.g. Allen & Leung, 2014). It has been suggested that if these natural food sources are preserved on farms, livestock predation could be reduced (Ott, Kerley & Boshoff, 2007; Avenant & Du Plessis, 2008; Du Plessis, 2013; PMF, 2016). It has also been suggested that through appropriate grazing management, by reducing herd size and preventing over-grazing, the habitats where natural prey occur will be less disturbed, resulting in higher prey diversity and numbers (Avenant & Du Plessis, 2008; Blaum, Tietjen & Rossmann, 2009; PMF, 2016). It is expected that a suitable grazing management strategy will also enable livestock to grow quicker, thereby reducing the potential risk of predation (PMF, 2016). It is, however, also possible

that some predators may switch to livestock as their main prey during certain periods of the year, most notably during their reproduction or lactation, and that some individuals may even “learn” to specialize on livestock (Avenant & Du Plessis, 2008; Fleming, Allen, Ballard & Allen, 2012; Du Plessis, Avenant & De Waal, 2015; also see Chapters 7 and 9). Predators also prey on livestock competitors and, in some cases, the benefit of reduced predation may not outweigh the cost of the increased competition arising from the loss of predators (Allen, 2015). These complex predator-prey relationships clearly affect livestock producers, but there remains a limited understanding of how these relationships can be managed to optimise livestock production and conservation goals.

Aversive deterrents

Conditioned taste aversion

Conditioned taste aversion (CTA) is used to repel target species from a specific prey type (Pfeifer & Goos, 1982; Bomford & O’Brien, 1990; Shivik & Martin, 2000; Shivik *et al.*, 2003; VerCauteren *et al.*, 2003). It entails the use of emetics placed in specific baits, usually carcasses of livestock, and as the predator scavenges on the carcass it becomes nauseous. The nausea is intended to cause avoidance of the prey species (Smith *et al.*, 2000). Field studies suggest that CTA has been effective in some cases (Ellins & Catalano, 1980; Gustavson, 1982). However, the majority of the available studies have found the method to be ineffective (Burns & Connolly, 1980; Conover & Kessler, 1994; Hansen, Bakken & Braastad, 1997). Significantly, predators develop an aversion against the baits but continue to kill livestock, presumably because the baits do not successfully mimic live livestock (Conover & Kessler, 1994) and because the predators are able to recognise the taste of the emetic (Strum, 2010). Hansen *et al.* (1997) also observed increased aggressiveness in predators that were exposed to treated baits, which ultimately resulted in a greater intensity of livestock killings. CTA has not been trialled in South Africa, but it is anticipated that it will suffer from similar problems to those experienced elsewhere.

Bio-fencing

Bio-fences (\approx bio-boundaries) are created by strategically placing scent marks or sounds that imitate the presence of conspecifics or other competitors in an area (Anhalt,

Van Deelen, Schultz & Wydeven, 2014). These were developed using the same principles as virtual fencing (see Box 6.1). Bio-fences are assumed to deter territorial individuals from entering a demarcated area or force residents to move out of the area (Anhalt *et al.*, 2014). The implementation of bio-fences is a relatively new concept (Schulte, 2016) and very little research has been conducted (Robley, Lindeman, Cook, Woodford & Moloney, 2015). Ausband, Mitchell, Bassing & White (2013) found that bio-fences effectively deterred wolves for the first year of study, but not in the second year. In contrast, Jackson, McNutt & Apps (2012) found that artificially placed scent marks resulted in an introduced African wild dog *Lycaon pictus* pack moving away from the periphery of their newly established home-range where the scent marks had been placed. However, Anhalt *et al.* (2014) found that a combination of artificially placed scent marks and foreign howls did not affect the territorial behaviour of wolf packs. In addition, Shivik (2011) found that human-placed coyote urine did not effectively repel coyotes. According to Ausband *et al.* (2013), the success of a bio-fence is influenced by a variety of factors, including *inter alia* the absence of direct conflict between predators, the absence of other signs (e.g. sounds imitating another competing predator) and the longevity of scent marks. It is clear that more research is needed on the use of bio-fencing in general, and specifically in South Africa.

Shock collars

Shock collars can be fitted to individual predators and programmed (or remotely controlled) to deliver an electric shock when the animal engages in a particular behaviour (i.e. attacking livestock) or transgresses a particular spatial boundary (Andelt, Phillips, Gruver & Guthrie, 1999). The technique requires that the predator is successfully captured, collared and released back onto the farm. Some promising results on the use of shock collars as a predation management method have been published (Andelt *et al.*, 1999; Hawley, Gehring, Schultz, Rossler & Wydeven, 2009). However, in situations where more common predator species have to be managed the practicalities and costs of collaring large numbers of individuals and re-releasing them onto extensive farming operations makes this technique untenable. In addition, the National Society for the Prevention of Cruelty to

Animals (NSPCA) in South Africa have stated in the past that they do not support the use of shock collars on wildlife as they consider them to be potentially cruel (Cupido, 2010).

Electric fencing

The electrification of existing fences (Figure 6.6) may increase their effectiveness at excluding damage-causing predators, because the predators will tend to avoid being shocked (McKillop & Sibly, 1988; Hygnstrom *et al.*, 1994). Sound construction and maintenance is, however, a prerequisite for electric fences to remain effective. For instance, Clark *et al.* (2005) found that in southeast Georgia in America, the success of black bears *Ursus americanus* in raiding bee-yards was contingent on a fence failure (through depleted batteries) and bear tracks were seen to follow the lines of successful fences, suggesting that bears approach fences but are deterred by an electric shock. However, when bears did cross disconnected electric fences, they consistently did so only a few days after battery depletion, suggesting that they “check” fences regularly. Electric fencing is also used extensively to protect livestock from dingoes in Australia (Bird, Lock & Cook, 1997; Yelland, 2001), and to protect threatened fauna from dingoes and other predators (Long & Robley 2004). In South Africa, Heard & Stephenson (1987) noted that the electrification of an existing “jackal-proof” fence resulted in fewer burrows underneath the fence and hence black-backed jackals were more effectively excluded. In addition, livestock farmers who used electric fencing in Kwazulu-Natal reported that it was generally successful at decreasing predation (Lawson, 1989). Similar results (although unpublished) have been reported in the Eastern Cape (Viljoen, 2015). Game farmers in Limpopo have also indicated that they are generally satisfied and that this measure is effective at limiting losses (Schepers, 2016). In the Western Cape, the use of electric fences is often cited as a successful method for excluding chacma baboons (Hoffman & O’Riain, 2012, Kaplan, 2013).

Electric fencing will likely be a cost-effective method in the long run in South Africa, despite the high costs initially (Viljoen, 2015). However, Beck (2010) found that electric fencing caused the electrocution of at least 33 different mammalian, reptilian and amphibian species across South Africa. In addition, Pietersen, McKechnie



Figure 6.6. The electrification of an existing fence generally increases its effectiveness at excluding predators. Electric wires close to the ground prevent predators from crawling underneath the fence. Placing wires on each side of the live wire close to the ground may prevent the electrocution of certain non-target animals. Photo: Niel Viljoen.

& Jansen (2014) found that although some Temminck’s ground pangolin *Smutsia temminckii* individuals were not instantly killed by electrocution, due to their long exposure to the electric current they became weak and eventually died from exposure. Nevertheless, it is possible to limit electrocutions from electric fences with appropriate planning and design (Todd *et al.*, 2009).

Provisioning Supplemental feeding

Although supplemental feeding has been successful in the Cape Peninsula, Western Cape to temporarily distract chacma baboons from raiding urban areas (Kaplan, O’Riain, Van Eeden & King, 2011), it has not been tested extensively in the livestock predation context (but see Van der Merwe *et al.*, 2009). Some game farmers in the North West Province make use of “jackal restaurants” to curb black-backed jackal predation on game species (John Power, 2017, pers. comm.), but the method’s effectiveness has not been scientifically evaluated. A major concern is that supplemental feeding could increase the fecundity of predators and the territorial behaviour and/

or social structure and diet of the predators may also be altered through provisioning (Kaplan *et al.*, 2011; Du Plessis, 2013; James, 2014; also see Chapters 7 and 9), increasing livestock predation in the long term. For example, Steyaert *et al.* (2014) found that brown bear *Ursus arctos* densities in Slovenia were higher compared to populations in Sweden mainly due to the impact of prolonged supplementary feeding practices in the former country. Consequently, human-bear conflict was also higher in Slovenia. However, Steyaert *et al.* (2014) noted that there could be variations within a population because not all individuals will visit supplementary feeding sites. Nevertheless, providing food subsidies to predators typically also has negative environmental benefits (Newsome *et al.*, 2014).

Non-lethal population control

Translocation

Translocation has been used to relocate predators to areas away from the existing conflict. A review by Linnell, Aanes, Swenson, Odden & Smith (1997) and a study by Weilenmann, Gusset, Mills, Gabanapelo & Schiess-Meier (2010) both show that this method is generally only successful when the animal can be relocated to an area with a relatively low density of conspecifics and where the same conflict will not occur (i.e. absence of species the predator was targeting). If these requirements cannot be satisfied, the translocated predator will likely disperse from the release site, sometimes back to the original site of conflict and/or the problem will merely be transferred to a new area. There is currently no scientific information on the usefulness of translocation to manage livestock predations in South Africa, although there are various groups actively involved in “rescuing” and translocating apparently damage-causing predators (e.g. CapeNature, 2017). A single study has shown the successful translocation of a leopard away from the conflict area (Hayward, Adendorff, Moolman, Dawson, & Kerley, 2007), but the consequences for livestock predation in this case are unknown. Monitoring the outcomes of these translocations is needed. It is prescribed by law that a permit to translocate a damage-causing animal in South Africa can only be issued once it has been shown that all other management interventions have been exhausted (NEMBA, 2004).

Fertility control

Fertility control includes interventions such as contraception and sterilization, and is employed to decrease birth rates (Shivik, 2006). Bromley & Gese (2001a) found that surgical sterilization of entire coyote packs in the US successfully reduced small livestock predation, presumably because coyotes kill more livestock when pups are present. Knowlton *et al.* (1999) envisaged that contraceptives could have a similar effect in coyote populations. Bromley & Gese (2001b) noted that surgical sterilization did not affect coyote territoriality or social behaviour. Similarly, in Saudi Arabia the sterilization of male hamadryas baboons *Papio hamadryas* did not alter troop composition and social structure for four years after sterilization (Biquand *et al.*, 1994). In addition, during those four years, only one male dispersed into another troop (Biquand *et al.* 1994). The latter study, however, was conducted to test the effect of fertility control on the raiding behaviour of hamadryas baboons and not livestock killing behaviour.

Despite the demonstrated effectiveness of fertility control to manage some predator populations, there are several limitations. If factors other than the presence of offspring influence livestock predation patterns, then fertility control may not be effective at reducing livestock killings (Knowlton *et al.*, 1999; Bromley & Gese, 2001a). Furthermore, fertility control can be time consuming and costly. In most cases it is impossible to identify the breeding individuals in a predator population and, as such, the successful application of fertility control would require the capture and sterilization or the application of contraceptives to all adults of one sex within a target population (Mitchell, Jaeger & Barrett, 2004; Shivik, 2004; Connor, Ebinger & Knowlton, 2008). Significantly, there are no species-specific contraceptives available that could be applied to baits, raising concerns around possible impacts on non-target species (Gese, 2003). Currently, no scientific evidence is available on the use of either contraception or sterilization for damage-causing predators in South Africa and given the broad distribution of many of the damage-causing predator species and their large numbers this method is highly unlikely to have application outside of small, isolated areas.

Producer management

Compensation schemes

Compensation is generally implemented to reduce the persecution of less common or protected species that kill livestock (Bulte & Rondeau, 2005; Rajaratnam, Vernes & Sangay, 2016). Although there are examples of compensation schemes that have successfully decreased retaliatory killing of predators (e.g. Bauer, Muller, Van der Goes & Sillero-Zubiri, 2015), a number of studies (Bulte & Rondeau 2005; Lamarque *et al.* 2009; Rajaratnam *et al.* 2016) highlighted shortcomings associated with compensation schemes. When compensation schemes are available, producers may reduce effort in protecting their stock. Consequently, livestock losses may actually increase (although it is possible to counter the latter behaviour – see Bauer *et al.*, 2015). It is also often difficult to monitor or verify predation claims or whether producers are complying with any terms associated with a specific compensation programme and thus the system may be abused. Compensation could be paid out irregularly, especially in developing countries, due to budget constraints. It could be difficult for less literate or isolated farmers to claim. People may be discouraged from claiming compensation because of the time and cost involved in the process (Bulte & Rondeau, 2005; Lamarque *et al.*, 2009, Rajaratnam *et al.*, 2016). In general, if compensation schemes are well administered and resourced, and measures are in place to successfully monitor and confirm claims of predation, the method may have some potential to limit persecution of rarer carnivore species (e.g. cheetahs, leopards). However, compensation is unlikely to be economically feasible where livestock predation is caused by more common species (e.g. black-backed jackals, caracals). Overall, compensation will ultimately only shift the economic costs of livestock predation from livestock producers to governments, conservation entities or the taxpayer and will not resolve livestock predation (i.e. compensation provides a viable conservation tool but an unfeasible tool to reduce livestock predation).

Insurance programmes

Insurance programmes rely on livestock owners paying a premium on a fixed basis that enables the contributor to be refunded in the event of losses due to livestock

predation (Madhusudan, 2003). Although insurance programmes can be successful for farmers where herds are relatively small and where livestock predation is relatively low (e.g. Mishra *et al.*, 2003), it is anticipated to be less feasible for larger livestock enterprises or where livestock losses are high (Du Plessis, 2013). This is because it is often difficult to monitor or verify the cause of livestock mortality with the consequence that most livestock losses, particularly of young, are categorised as unknown. Ultimately the lack of accurate information on depredation rates and the variable success of different methods to mitigate predation may make it difficult for insurance companies to develop viable insurance models/plans (Du Plessis, 2013). Clearly work is needed to overcome these limitations.

Financial incentives

Bounties are generally used as a measure to control invasive or “problem-causing” species. People are paid for every individual hunted (see Lethal Predator Management section) of a species that are considered undesirable (Neubrech, 1949; Hrdina, 1997). Although this measure has been used extensively in the past as a predation control method by various governments throughout the world, it has been abandoned by many (e.g. Neubrech, 1949; Beinart, 1998; Schwartz *et al.*, 2003). It is still officially implemented in some countries (e.g. Australia, Canada, US) but there is a growing consensus that it is not an effective predation management method (Glen & Short, 2000; Pohja-Mykra, Vuorisalo & Mykra, 2005; Proulx & Rodtka, 2015). Furthermore, as highlighted by the current chapter, various environmental and ethical concerns arise where bounties are used to reduce predator numbers.

Trophy hunting of damage-causing species or individuals is sometimes proposed as another form of financial incentive to reduce predation. The basic premise of this strategy is that if livestock owners have the opportunity to hunt a known damage-causing species or individual that occurs on their property, and receive the income from this, they will become more tolerant of the species (Treves, 2009). However, in cases where a permit needs to be granted to hunt a specific damage-causing individual, it may be difficult to identify the culprit (Treves, 2009). Furthermore, it might be difficult to verify damages caused by a specific individual and hence the

approach could be subject to fraudulent claims (Treves, 2009). It is also possible that the economic benefits may only accrue to selected individuals (Dickman, Macdonald & Macdonald, 2011). Hunting may also have unintended social disruptions in the local predator population, which could lead to an increase in livestock predations in the long term (Treves, 2009; Peebles *et al.*, 2013; Loveridge *et al.*, 2016; Teichman *et al.*, 2016; also see “Shooting”).

Financial incentives can also be implemented directly through the payment of subsidies/tax rebates or indirectly through the development of “predator friendly” brands. The main aim of these two measures is to motivate producers to implement or commit to certain predation management methods (Mishra *et al.*, 2003) and thus they are not considered to be predation management *per se* (similar to laws and regulations – see Box 6.2). Nevertheless, it can be used as an important economic tool which may assist in overall predation management. Historically, government subsidies were widely offered to livestock producers in South Africa to implement certain predation management methods (Beinart, 1998), but

this is no longer the case. More recently, some “predator friendly” branding has also been proposed in South Africa (Avenant, De Waal & Combrinck, 2006, Smuts, 2008). When livestock owners subscribe to such a brand, they commit to implement only certain (generally non-lethal) predation management methods (Treves & Jones, 2010). Such an approach theoretically enables producers to charge a premium for their products and thereby offset the potential costs associated with the implementation of the prescribed predation management methods (Smuts, 2008). Although “wildlife friendly” brands have been implemented successfully before in subsistence communities (Marker & Boast, 2015), there are some questions regarding its use in commercial settings in South Africa. Notwithstanding the major issue of regular compliance monitoring in extensive areas (Treves & Jones, 2010), “wildlife friendly” branding is a marketing tool which targets more wealthy consumers. “Predator friendly” branding may thus not succeed as a viable financial incentive for the majority of commercial livestock producers.

Box 6.2 The role of laws and regulations in livestock predation management

Predation management is widely guided by various laws and regulations which attempt to control how certain predation management methods are applied, or to force producers to not use certain methods or not to kill certain species (also see Chapter 5). Although these laws and regulations will presumably be successful in most cases to control predation management, there are examples in South Africa where laws pertaining to wildlife management have been successfully challenged and annulled by the courts because they lacked adequate scientific evidence [e.g. SA Predator Breeders Association vs. Minister of Environmental Affairs (72/10) ZASCA 29 November 2010]. There are also examples where stakeholders disregard certain laws (e.g. the regulations placed on the use of poisoning as a predation management tool) out of desperation, or because they feel that these regulations threaten or exclude their interests (Du Plessis, 2013). The unlawful use of certain prohibited methods on livestock farms in South Africa is exacerbated by the extensive nature and remote location of these farms, which often complicate law enforcement. Furthermore, when predation management laws and regulations become overly prescriptive farmers may feel that they do not have any control over management decisions, and this may influence how and what predation management methods they implement. For instance, Lybecker, Lamb & Ponds (2002), Kleiven, Bjerke & Kaltenborn (2004) and Madden (2004) noted that when certain wildlife species were protected, and their management regulated by excessive laws on private land, landowners felt that they lost control over what happened on their land. This contributed

to these farmers developing a dislike towards the protected wildlife and the prescribed management methods. Similarly, Bisi, Kurki, Svensberg & Luikkonen (2007) and Bath, Olszanska & Okarma (2008) found that people showed more dislike for specific species once they were instructed on how to manage these species.

Lethal predator management

Shooting

Shooting is generally applied in two ways. Firstly, it is intended to decrease the risk of predation by reducing overall predator numbers in an area, either by shooting predators opportunistically or through concerted killing operations (Hygnstrom *et al.*, 1994; Mason, 2001). Secondly, shooting is used to eliminate damage-causing individuals in a specific area after a livestock predation event (Hygnstrom *et al.*, 1994; Reynolds & Tapper, 1996; Mitchell *et al.*, 2004). In South Africa, shooting, in conjunction with calling, is often employed at night to control black-backed jackals (Snow, 2008; Figure 6.7). Currently, shooting is the most frequently reported predation management method across all types of livestock farms in South Africa (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016), which can often be linked to its recreational value. Despite its popularity amongst farmers there is only limited scientific information on its efficacy in South Africa.

When shooting is used, population reductions are generally considered a species-selective method because only individuals from the target species are shot. The method has been used to effectively decrease coyote and lynx predation on sheep in the US and Norway, respectively (Wagner & Conover, 1999; Herfindal *et al.*, 2005; Connor *et al.*, 2008). These successes were due to some (or most) of the individuals responsible for livestock killings being removed. However, in a questionnaire study conducted on livestock farmers in Kwazulu-Natal, one of the respondents reported that over a period of three years, despite shooting black-backed jackals every year (between 39 and 54 jackals annually), he continued to lose more than 100 sheep a year (Humphries *et al.*, 2015; also see Thomson, 1984). Additionally, Minnie *et al.* (2016) in a study on the effect of extensive shooting

on black-backed jackal populations on livestock farms in the Eastern and Western Cape, found that jackal populations on these farms were generally younger and more unstable compared to populations on nearby reserves. This was because sustained shooting on the farms resulted in the disruption of the normal, mutually exclusive territorial system of black-backed jackals and created vacated areas for younger dispersers. Minnie *et al.* (2016) also demonstrated that the populations on the farmland compensated for population reductions by reproducing at a younger age and by carrying more fetuses (also see Loveridge, Searle, Murindagomo & MacDonald, 2007; Chapter 7). Minnie, Zalewski, Zalweska & Kerley (2018) also showed that shooting created



Figure 6.7. A variety of devices are commercially available that can be used to call and shoot black-backed jackals in South Africa. It is widely believed that the unselective and incorrect use of this method may have, however, contributed to exacerbate livestock predation in South Africa. Photo: Niel Viljoen.

source sink populations, with jackal recruiting into areas with control through shooting, with both reserves and other livestock farms serving as sources.

However, in the US, Wagner & Conover (1999) maintained that aerial gunning (\approx shooting from fixed-wing aircraft) of coyotes during the winter to control predation on sheep decreased the effort for predation management during the following summer. Resultantly, the authors contended that the financial benefits of this approach outweighed the costs by 2.1:1. The costs and benefits of aerial hunting may vary depending on several factors, including the type of aircraft used, experience of the pilot and aerial hunter, size of the area hunted, topography, density of foliage, predator species targeted and weather conditions (Wagner & Conover, 1999). Collectively culling black-backed jackals on an annual basis via helicopter by groups of small stock farmers, generally in the months preceding lambing, is a widespread practice in many parts of South Africa (N. Avenant, 2017, pers. comm.). Although farmers claim that the collective hunts reduce their livestock losses significantly, to date it has not been quantified how cost-effective these operations are in the long term.

Shooting used in conjunction with calling is generally considered a relatively inexpensive, species selective and effective way to reduce predation in the short-term (Reynolds & Tapper, 1996; Mitchell *et al.*, 2004). In a study in the US, calling has been shown to attract more male coyotes than females, presumably because they are the main defenders of territories (Sacks, Blejwas & Jaeger, 1999). Calling has also been noted to successfully attract breeding coyotes (\approx the individuals which generally kill more livestock), presumably because of their need to defend their litters (Sacks *et al.*, 1999). Knowlton *et al.* (1999) concluded that if calling is restricted to the areas where predation occurs, it could be used effectively to attract damage-causing coyotes. However, despite the observed successes, Windberg & Knowlton (1990) noted that calling in their study area attracted more juvenile coyotes and they believed this was due to an avoidance behaviour which was developed in the older individuals. Although some in South Africa claim that calling and shooting is successful at reducing black-backed jackal numbers (Du Plessis, 2013), there is a lack of scientific information in this regard. There is also consensus that where calling and shooting is applied incorrectly and

indiscriminately, it will result in habituation (N. Viljoen, 2017, pers. comm.).

Denning

Denning involves the killing of young predators at their dens without killing the adults. It is based on the same assumption as reproductive interference, which is that by removing the young, there will be a decrease in depredation because the adults no longer need to provision their young (Hygnstrom *et al.*, 1994; Gese, 2003). Till & Knowlton (1983) showed the effectiveness of denning for controlling coyote predation on sheep in Wyoming, US. In this instance, incidences of predation on livestock decreased by 87.7% and total livestock kills decreased by 91.6% after the removal of the pups. Gese (2003), however, noted that den detection can be very time consuming depending on, amongst others, the cover and terrain, although domestic dogs could potentially be trained to detect dens. Denning also requires annual implementation and provides only a short-term solution (\approx less than 12 months). Furthermore, if factors other than litter presence influence livestock predation patterns, denning will not necessarily be effective (Till & Knowlton, 1983). Denning may potentially also trigger compensatory breeding in certain predators (see Loveridge *et al.*, 2007; Minnie *et al.*, 2016).

Hunting dogs

Although it is possible for a well-trained hunting dog pack to be selective, hunting with dogs is generally perceived to be non-selective and unethical (Smuts, 2008; Snow, 2008). The selectivity of this method may increase if employed soon after a predation event and at the predation site (Snow, 2008). Dogs have been used extensively in the past to capture predators in South Africa (Hey, 1964; Rowe-Rowe, 1974; Pringle & Pringle, 1979). However, it is currently illegal in South Africa for dogs to capture a predator although they can still be used to chase or point (\approx dogs search for the target and bark when they find it) at the predator (NEMBA, 2004). Hey (1964) demonstrated that seasonality, climatic conditions and topography can all influence the successfulness and specificity of dog hunts. Further, based on an interpretation of the information obtained from historical hunting records in South Africa, the efficacy of dog hunts is questionable (Gunter, 2008). According to

Gunter (2008), when hunting clubs used dogs to remove predators, neither predator numbers nor livestock predation decreased considerably. This was attributed to climatic conditions, the fact that hunters sometimes pursued predators long after damage was reported, and the capability and motivation of hunters. However, Gunter (2008) did caution that drawing conclusions from such historical data may be limited owing to the incomplete nature of the data. Overall, hunting dogs may be a good option to track damage-causing predators in certain conditions (e.g. in mountainous or bushy terrain), but then it is important to ensure that the dogs are well trained and under the control of a competent handler. It remains, however, crucial to gather more information on the efficacy of this method.

Poisons

Poisoned baits are considered highly unselective and their use is outlawed in many countries (Sillero-Zubiri & Switzer, 2004), including South Africa (PMF, 2016). In South Africa, poisoned baiting is generally applied by strategically placing a treated livestock carcass or a piece of bait in the field (e.g. at burrows dug under a border fence) or by scattering treated pieces of meat where predator activity is visible (Snow, 2008). To target baboons, poisoned bait is placed in a plastic bottle or small container that can only be accessed and opened by primates through manipulation or biting (M. Tafani, 2017 pers. comm.). There is not much scientific information on the effectiveness of this method to decrease livestock predation in South Africa. However, in other countries, poisoned baiting has been shown to be successful at decreasing the population sizes of some predators (Gunson, 1992; Eldridge, Shakeshaft & Nano, 2002; Thomson & Algar, 2002; Burrows *et al.*, 2003; Allen, Allen, Engeman & Lueng, 2013b). However, Gentle, Saunders & Dickman (2007) found that the numbers of more common species, such as European red foxes, recovered quickly due to immigration. Eldridge *et al.* (2002) also noted that despite a decline in dingo densities initially, there was no difference in damage to cattle between poisoned and un-poisoned areas in Australia. Consequently, the authors concluded that most of the damage-causing individuals were not affected by these baits, presumably because they did not utilize them as food sources (Eldridge *et al.*, 2002; 2016). It is alleged

that some black-backed jackal individuals may show similar avoidance behaviour towards poisoned baits (Snow, 2008). Nevertheless, the most significant issue with respect to poisoned baiting in South Africa remains its unselective nature (Figure 6.8). For example, the Wildlife Poisoning Database of the Endangered Wildlife Trust (EWT) lists 174 individual incidents of poisoning of non-target raptor species in South Africa resulting in 2023 mortalities (A. Botha, 2017, pers. comm.).



Figure 6.8. One of the most significant issues with respect to poisoned baiting in South Africa remains its unselective nature. Scavengers are especially at risk to this method. Photo: André Botha.

The coyote getter or M44 (the latter is a modification to the original coyote getter) is a mechanical device with a cartridge that ejects a poison (generally in the mouth) when a trigger is pulled by a predator (Blom & Connolly, 2003). Compared to poisoned baiting, “getters” can be considered a more acceptable method because *inter alia*: (1) the “getters” are more selective (\approx an animal has to trigger the “getter” for the poison to be released) (2) the poison is secure and cannot be carried away by an animal; and (3) the poison degrades slower in “getters”, because it is protected in the cartridge from the elements, and thus yields a lethal dose for longer. In South Africa, it is currently illegal to use traditional forms

of “getters” because these devices use ammunition (PMF, 2016). Furthermore, the method is widely outlawed because of its perceived non-selectiveness and the potential environmental impact of the poisons used (Sillero-Zubiri & Switzer, 2004; Snow, 2008). However, Marks & Wilson (2005) have demonstrated that it is possible to make these devices more species-specific. Bothma (1971) tested the efficiency of coyote getters to kill black-backed jackals over a 60 day period in the former Transvaal and found that almost 80% of all triggers caused by black-backed jackals occurred within the first 14 days, thereafter the trigger rate gradually decreased until almost no triggers occurred in the last 20 days. However, only 45% of the coyote getters that were triggered successfully killed black-backed jackals (Bothma, 1971). Brand, Fairall & Scott (1995) and Brand & Nel (1997) studied the avoidance behaviour of black-backed jackals towards these devices. The two studies both found a capture bias towards younger individuals, with older individuals showing avoidance behaviour. Sacks *et al.* (1999) observed a similar bias in coyotes and concluded that M44’s would not be effective at controlling coyote depredation since it is usually the older, breeding coyotes that are responsible for most livestock killings. Importantly, the ability of certain damage-causing predators to avoid coyote getters, together with them being able to be activated by several African fauna species, make these devices problematic in the South African context.

Poison collars (≈ collars with pouches that contain a lethal dose of poison; Figure 6.9) only target predators that attack livestock (Mitchell *et al.*, 2004). These collars are often considered an effective and more ethically acceptable alternative to removing damage-causing individuals that evade other control methods (Gese, 2003; Sillero-Zubiri & Switzer, 2004; Smuts, 2008; Snow, 2008). Poison collars have been successful at controlling coyotes in the US under experimental conditions (Connolly & Burns, 1990; Burns, Zemlicka & Savarie, 1996). Connolly & Burns (1990), in field tests in the US, also recorded a puncture rate by coyotes into poison collars of 43%. It was, however, not clear how many coyotes were killed in the latter experiment. Blejwas, Sacks, Jaeger & McCullough (2002) found poison collars to be the most effective method to reduce sheep losses compared to non-selective methods and instances where

no predation management efforts were implemented. Burns *et al.* (1996) further showed that the coyotes in their pen tests did not show any aversive behaviour towards poison collars. Despite its apparent successes, accidental spillages of poison from the collars could kill livestock (Burns & Connolly, 1995), and scavengers can be affected when they eat predator carcasses (Burns, Tietjen & Connolly, 1991; Snow, 2008), although this can be prevented to an extent by using certain poisons and specific dosages. In South Africa, Avenant, Steenkamp & De Waal (2009) demonstrated that the use of poison collars, in combination with the use of non-lethal methods (bells, stock management, and range management), on a farm in the Western Cape was effective at reducing caracal predation on sheep. Importantly, to inhibit habituation, the poison collars were fitted to stock only when a loss to a caracal occurred and removed as soon as the losses stopped (Avenant *et al.*, 2009). To use poison collars in South Africa, a valid permit is required and only sodium mono-fluoroacetate (≈ Compound 1080) can be used (NEMBA, 2004).



Figure 6.9. Toxic collars are generally considered a very target-specific method and the safest application of poison. Photo: Niel Viljoen.

Trapping

Trapping generally intends to capture a predator alive, although under most circumstances in South Africa, the target predator is killed after it has been trapped. A variety of traps exist, including cage traps, foothold traps, snares or killer traps (Figure 6.10). The former

three traps are generally used in conjunction with a lure to attract the target species. In general, trapping is likely to be very specific for solitary felids that cache and return to their kills (e.g. caracals, leopards) if the trap is set at the kill site. Cage traps can be selective and humane if non-target species are released and traps are checked regularly. Brand (1989) demonstrated the effectiveness of cage traps for capturing caracals and chacma baboons in the former Cape Province and noted that it is a relatively

inexpensive method for capturing predators. However, Brand (1989) did not test the effectiveness of cage traps to reduce livestock predation. Thus, it is not possible to determine the cost-effectiveness of this method. A major disadvantage of cage traps and all methods of trapping is that it is not possible to know whether it is the specific damage-causing individual that has been caught (but see earlier in this paragraph), and they require considerable effort to bait and check on a regular basis.



Figure 6.10. The use of traditional indiscriminate traps like the killer trap (left) will be difficult to motivate from an environmental or ethical perspective, while it may be more acceptable to implement modified traps (right) that will likely cause less harm to a captured individual or that are more species selective. Photos: Niel Viljoen.

A leghold device consists of two interlocking steel jaws that are triggered when an animal of sufficient weight steps on the trigger plate. The use of leghold devices (especially the older gin traps) is also often strongly challenged because they are viewed as non-selective and inhumane (Smuts, 2008). Although some evidence exists to show that this method can be effective to capture certain damage-causing predators in South Africa (Rowe-Rowe & Green, 1981; Brand, 1989), it is not clear whether this method alleviates livestock losses. According to an unpublished survey by the EWT, 50% of respondents who indicated that they used gin traps (64 of the total number of respondents) reported that they captured non-target species (Snow, 2008). In addition, although studies by Rowe-Rowe & Green (1981) and Brand (1989) found that gin traps were effective in capturing black-backed jackals and caracals, the traps

were relatively unselective and also captured non-target species. It has been suggested that the species selectivity of foothold traps (and possibly also other forms of traps) could be improved by the correct calibration of the traps and the selection of the correct lure (N. Viljoen, 2017, pers. comm.). Indeed, McKenzie (1989) and Kamler, Jacobsen & MacDonald (2008) showed that specially modified traps captured fewer non-target species and caused limited injuries to the captured individual. Currently, only foothold traps with offset and/or padded jaws (\approx soft traps) are permitted in South Africa (NEMBA, 2004).

Three types of snares exist, namely body-, neck-, or foot-snares (Gese, 2003; Turnbull, Cain & Roemer, 2011). The former two consist of a looped wire cable which tightens around the body or neck once the animal passes through it and thrusts forward. These snares are

generally set at a hole under a fence where predators pass through, along pathways or at den entrances. Foot snares are set on the ground, generally in pathways, and when an animal steps on the trigger, the cable is released and tightens around its foot (Logan, Sweanor, Smith & Hornocker, 1999; Gese, 2003). Because of their relative simplicity, low cost and ease of handling, neck snares are often used in the US to control damage-causing predators (Gese, 2003; Turnbull *et al.*, 2011). However, snares are also viewed as non-selective and inhumane by some groups (Smuts, 2008). The selectivity of snares can be increased with the addition of break-away locks or stops, setting at the height of the target species, or for foot snares by adjusting the sensitivity of the trigger plate (Frank, Simpson & Woodroffe, 2003; Turnbull *et al.*, 2011).

Unlike other forms of trapping, a killer trap (\approx "doodslaner") intends to kill the captured animal. It is uncertain to what extent this device is still used in South Africa. It is usually placed at an opening under a fence and when a predator (or other animal) pass through, the device is triggered and impacts the animal on its head or body. The force of the device generally kills the captured animal or cause severe injuries (Ramsay, 2011). Although there is no scientific information on the use of this device, its indiscriminate nature will likely make it an untenable option.

INTEGRATION OF METHODS WITHIN AN ADAPTIVE MANAGEMENT FRAMEWORK

The preceding section on Predation Management Methods discusses the different predation management methods that are used both globally and in South Africa. While the lack of appropriately designed research to test the short and long-term efficacy (and side-effects) of each method precludes prescriptive assignment for particular predator problems, there is a growing acceptance among both scientists (Hygnstrom *et al.*, 1994; Knowlton *et al.*, 1999; Avenant *et al.*, 2009; Du Plessis *et al.*, 2015; Eklund *et al.*, 2017) and professional predation managers (De Wet, 2006; PMF, 2016) that management needs to be adaptive and draw on different methods depending on the local context (also see Box 6.3). Reasons for this perspective include the following insights (although the

list is not exhaustive):

1. Unselective lethal management: The removal of territorial dominant individuals encourages the influx of dispersing, non-territorial individuals (Loveridge *et al.*, 2007; Avenant & Du Plessis, 2008; Minnie *et al.*, 2016) that could negatively impact the density of natural prey (Avenant & Du Plessis, 2008; Avenant *et al.*, 2009) and could be more prone to predate on "unnatural" prey (i.e. livestock) (Avenant, 1993; Avenant *et al.*, 2006).
2. Confounding variables: Particular combinations of methods may be counterproductive (Hygnstrom *et al.*, 1994; N. Avenant, 2017, pers. comm.; N. Viljoen, 2017, pers. comm.). For example, the simultaneous removal of predators and the introduction of LGDs. LGDs are hypothesised to be successful because they prevent predation by keeping predators away from livestock flocks or herds (Allen *et al.*, 2016). Presumably, if the farmer ceases to implement lethal control after the introduction of LGDs, predators will generally remain in the larger area and only avoid the area/camp/part of the camp where the LGD is present (\approx they do not leave the farm/abandon their territory). However, if lethal removal of predators continues, immigration of other predators may still occur, with short term increases in densities, territorial disputes, less natural prey, and potentially more livestock losses (see above). LGDs may also be susceptible to the predator removal techniques. In this example, a combination of LGDs and the lethal removal of predators may not only be counterproductive, but confound the efficacy of either method. The net outcome in this example is to erroneously dismiss LGDs as a potentially viable management option.
3. Scalability: A non-lethal method may be successful at the scale of an individual camp or farm, but ineffective at the landscape level within an entire district with hundreds of farms. In such cases, a method may simply deflect predators to other areas and regional losses may be similar or higher due to immigration. In instances where an animal is conclusively shown to prefer livestock and could be removed with a highly selective

lethal method then this might be preferable to a non-lethal method that merely deflects it to a neighbour, thus exacerbating their livestock losses.

4. **Habituation:** Given the learning capacity of mammals in general and social carnivores in particular (Box & Gibson, 2009), the overuse and misuse of specific methods may greatly increase the rate at which predators habituate to them (see "Predation management methods"). It is thus essential for the effectiveness of specific methods to be carefully monitored and disused before predators habituate to them. This can be achieved by frequently changing methods to maintain high levels of unpredictability and aversion in the landscape that livestock frequent.

Currently, there is limited scientific information to demonstrate the value of integration of different predation management methods in South Africa (Avenant

et al., 2009; Du Plessis, 2013; McManus *et al.*, 2015). Avenant *et al.* (2009) demonstrated how a combination of rangeland management practices (\approx management of the natural prey base), livestock management practices (\approx lambing in designated camps; regular and continuous flock monitoring and moving; removal of carcasses), preventative non-lethal predation management methods (\approx bells, protection collars) and selective lethal predation management methods (\approx poison collars) were integrated and interchanged effectively to decrease damages by caracal on a sheep farm in the Beaufort-West district, Western Cape. In this instance, Avenant *et al.* (2009) confirmed that caracal predation could largely be prevented with non-lethal methods used in such a way so as to prevent habituation. It is accepted that in some cases lethal alternatives may have to be used to remove damage-causing individuals that are not deterred by preventative methods (Viljoen, 2015, PMF, 2016; Viljoen, 2017).

Box 6.3 Adaptive management recommended to farmers in the absence of a clear, scientifically informed management strategy

In the early 1900s to mid-1990s, many livestock owners in the then Cape province relied on government subsidised jackal proof fencing together with guarding animals such as donkeys, Ostrich and cattle to limit losses to predators. If farmers became aware of localised damage they typically responded by concentrating predator management efforts in that specific area. Methods included walk-in traps, gin traps, coyote-getters and chasing with dogs/shooting (Beinart, 1998; De Wet, 2006; Stadler, 2006). This approach integrates preventative (exclusion with fencing) and retaliatory (both lethal and non-lethal) methods. It also relied heavily on the constant patrolling of fence lines, stock counts and looking for spoor and other signs (e.g. scat) of "problem animals". A change in management actions following an observed change in losses or predator presence is an excellent example of adaptive management which filled the vacuum created by the absence of robust and systematic scientific research. Importantly, constant communication between neighbours and communities lead to similar methods being practised over very large areas and the net effect was an effective predation management system built on local knowledge, professional opinion and advice from predator management efforts around the world.

In the last c. 50 years the socio-political and ecological environments have changed markedly in South Africa, which can be seen in the levels of livestock losses and current farming methods. Changes in labour law, land claims, minimum wages and reduced subsidies to farmers (see Chapter 2) have translated into less "feet on the ground" as more farmers farm with less workers on more than one farm. In

addition there are important landscape-level changes apparent in farming regions including many farms belonging to “weekend farmers” (less monitoring and predation management), and more game farms, state conservation, forestry and mining areas, all with different damage-causing animal management needs. In addition, jackal proof fences are old and dilapidated in many areas and not capable of limiting the movement of dispersing predators onto farms. Together these factors are generally perceived to have impeded coordinated and landscape level adaptive management strategies necessary to thwart predators. Thus, despite the fact that many more management methods have become available (see Table 6.1), both the number of stock losses and the number of damage-causing animals have apparently also increased, and farmers are today more frustrated with the situation than ever before (Du Plessis, 2013). Many professional predation managers and farmers are of the opinion that the incorrect application and integration of methods are at least partially to blame for the escalating livestock losses (see Avenant & Du Plessis, 2008). Although virtually nothing has been published in South Africa on this topic in scientific papers (see Du Plessis, 2013; McManus *et al.*, 2015), these practitioners still agree that combinations of both preventative and retaliatory methods, with definite time periods and set intervals, should be used. This approach has international support, including the USDA National Wildlife Research Center in the US (Hygnstrom *et al.*, 1994; Knowlton *et al.*, 1999), and in Australia (Anon. 2014).

Neither the notion of striving for the single “silver bullet” method nor using the entire toolbox (see section on Predation Management Methods) simultaneously are currently supported. For farmers commencing with predation management, professional opinion is that a well-constructed and maintained predator fence around high risk areas, such as lambing camps, is an essential first step towards managing your livestock and predators. In deciding which other methods to use thereafter the farmer, in consultation with a professional, should consider the geography of the farm and which habitats and hence camps will be preferred by which predators, the life history and behaviour of the predators in the general area and the diversity, distribution and availability of the natural prey. Before applying any specific method(s) the goal and likely outcomes should be communicated to neighbouring property owners as there will likely be direct (\approx predator displaced to their farm) or indirect (\approx more competition from wild herbivores for forage) consequences of the action. If a farmer/manager observes that a method is no longer effective it should be withdrawn immediately and withheld in the short term to avoid habituation. When unacceptably high losses can be ascribed to predators, the most appropriate retaliatory methods should be used with reference to the behaviour of the target species and the relative success and welfare considerations of the different methods (e.g. cage traps for caracal but with cages checked at least once daily). Both lethal and non-lethal methods should be considered, with the aim always to prevent the specific damage-causing individual(s) from accessing livestock. In a situation where exclusion fencing is well constructed and maintained, the number of predators gaining access to that specific area (e.g. the lambing camp) will be small. Hence any lethal management within the camp (e.g. call and shoot) is likely to target a damage-causing individual and greatly reduce losses in the short term. Intimate knowledge on the predator’s biology, behaviour and the probability of them habituating to a specific method are critical components of the selection, application and withdrawal of a specific method or combination of methods. The effective monitoring and understanding of the specific farm system and the broader ecosystem that it occurs in are also critically important components of a successful predation management strategy.

CONCLUSION

A variety of management methods are available to counter predation on livestock. From our assessment, it is evident that most of these methods have been used or trialed in one form or another in South Africa. However, the biggest issue is the paucity of reliable, experimental data (see Box 6.4) on their overall efficacy internationally (see Treves *et al.*, 2016; Eklund *et al.*, 2017), and the fact that little has been done in the South African context,

which means that it is not possible to scientifically accept or refute any specific method. This is not to say that these predation management methods are ineffective, but that we cannot tell if they are or not given the lack of robust data. In most cases, predation management in South Africa is therefore currently based on a combination of personal experiences and educated guesswork (Avenant & Du Plessis, 2008; Minnie, 2009; Du Plessis, 2013).

Box 6.4 Understanding the scientific value of different information sources

A relatively large pool of publications on predation management, as discussed in this chapter, is available to draw information from. However, it is important to understand the shortcomings that are associated with the different information sources.

Anecdotal information: Anecdotal information generally describes personal experiences and in most cases lacks any level of scientific scrutiny. This type of information should thus be used with caution. However, in some cases anecdotal publications may provide some valuable insight on a specific topic. In such cases, it may prove valuable to validate other sources of information or to highlight relevant research topics (NRC 2004).

Theses, dissertations and semi-scientific (quasi-scientific) information: Although these types of publications often follow some sort of peer-review process, they are generally not exposed to the same level of scientific scrutiny as peer-reviewed publications. Furthermore, it is likely that the research culminating into these publications follows some form of recognized research methodology or standard. In many instances, the results of theses, dissertations or semi-scientific publications are not followed through to peer-reviewed publication. However, the results could still provide valuable information which is often the only information source on a specific topic (Du Plessis *et al.*, 2015).

Peer-reviewed information: Peer-reviewed publications are (generally) subjected to rigorous scientific scrutiny and are generally recognised as a credible source of information. However, Treves *et al.* (2016), Eklund *et al.* (2017) and Allen *et al.* (2017) cautioned against the absence of scientific rigidity of many experiments reported in scientific publications are performed, this therefore precluding strong inference. A review by Treves *et al.* (2016) of publications on predation management in North America and Europe found that very few of the experiments that have been conducted in these publications conformed to rigorous testing using their so-called “gold standard” for scientific inference (\approx these experiments did not randomly assign control and treatment groups and the experimental designs did not avoid biases in sampling, treatment, measurement or reporting). Consequently, Treves *et al.* (2016) suggested that publications which do not meet the “gold standard” should be disregarded when predation management tools are designed or implemented. It is however important to acknowledge that, although peer-reviewed information is not flawless in many cases, it is the most reliable information to base current understanding of a specific topic upon (NRC 2004).

However, based on what scientific evidence is available, we are able to conclude that (but see Treves *et al.*, 2016; Eklund *et al.*, 2017; Van Eeden *et al.*, 2017):

1. The predation management methods employed by a farmer will vary depending on *inter alia* the damage-causing species that is being targeted, the type of livestock operation, season, location, and the environmental conditions (also see Eklund *et al.*, 2017; Van Eeden *et al.*, 2017).
2. Unselective, lethal control (\approx blanket removal of damage-causing species) may be counterproductive in the long term;
3. Unselective, lethal control is generally the most indiscriminate and hence may raise the most ethical and biodiversity concerns amongst stakeholders (also see Chapter 4);
4. Although some predation management methods are expensive to implement (e.g. fencing), it is possible that they may prove very cost-effective techniques in the long term;
5. There is increasing evidence to suggest that certain non-lethal methods (when used in combination) can successfully decrease livestock predation and be cost-effective;
6. Many predators have the ability to become habituated to predation management methods, supporting the concept that a suite of methods should be used and alternated.

Most importantly, it must be acknowledged that predator control does not always equate to predation management. While the former may be effective at reducing predator numbers in an area, in many instances it might not be effective to decrease livestock predation in the long term and also have various negative environmental and ethical consequences. Thus, when predation management is planned, the objective should not be to eradicate all predators in an area because it may not successfully address the problem of livestock predation (also see Eklund *et al.*, 2017). We advocate the livestock owner utilizing a wide variety of complementary strategies (including selective, lethal methods where necessary) in order to protect his/her animals (see Box 6.3). We caution that no single approach should be regarded a panacea for HPC in South Africa and that in most cases additional, applied research of the appropriate scientific standards (i.e. randomised with repeats and controls) is urgently required (see Mitchell *et al.*, 2004; Treves *et al.*, 2016; Eklund *et al.*, 2017; van Eeden *et al.*, 2017; Box 6.5). By their very nature, this may mean that assessments of the efficacy of lethal techniques will require the lethal removal of predators. A careful assessment of local conditions, the cultural and religious context, ethics and the socio-economic position of the landowner(s) is required before any management intervention is prescribed or implemented.

Box 6.5 Knowledge gaps related to predation management in South Africa

There is a general lack of information on the management of livestock predation in South Africa and to a large extent internationally (for both lethal and non-lethal methods) and it is virtually impossible to highlight specific research questions. Considering the large scale lack of information, we envisage that it may be necessary to prioritize research on specific management methods in future (e.g. target specific methods, non-lethal methods, or ethically acceptable methods; see Chapter 4). It is important that this research is of an appropriate scientific standard (i.e. randomised with repeats and controls - see Mitchell *et al.*, 2004; Treves *et al.*, 2016; Eklund *et al.*, 2017; van Eeden *et al.*, 2017). It is also important that this research is done at spatial and temporal scales relevant to the livestock production contexts they are intended to benefit and the species they are suspected to affect.

For each individual method that is studied we recommend focusing on:

1. The effectiveness of the method for decreasing livestock predation, in both the short and long term and preferably in different settings;
2. The cost-effectiveness of the method;
3. The potential environmental and ecological impacts of the method.

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CHAPTER 6

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BIOLOGY AND ECOLOGY OF THE BLACK-BACKED JACKAL AND THE CARACAL

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INTRODUCTION

Globally, several carnivore species have been implicated as livestock predators, these ranging in body size from the mongoose (Herpestidae) (e.g. Minnie, 2009) to the tiger *Panthera tigris* (Gusset, Swarner, Mponwane, Keletile & McNutt, 2009; Van der Merwe, Avenant & Lues, 2009a) and bears (e.g. Li, Buzzard, Chen & Jiang, 2013). However, medium-sized canids and felids are most often implicated in livestock predation. For example, red foxes *Vulpes vulpes* – the most widely distributed canid species apart from domestic dogs *Canis lupus familiaris* – attack and kill livestock both in their natural and introduced ranges (Sillero-Zubiri, Hoffmann & MacDonald, 2004); coyotes *Canis latrans* and dingoes *Canis lupus dingo* are the dominant predators of livestock in North America and Australia, respectively (Sillero-Zubiri et al., 2004). In addition, golden jackals *Canis aureus* prey on livestock in Africa, Europe and the Middle East (e.g. Yom-Tov, Ashkenazi & Viner, 1995). Furthermore, the Eurasian lynx *Lynx lynx* and to a lesser extent bobcats *Lynx rufus* have been implicated in livestock predation in Europe and North America, respectively (see Inskip & Zimmermann, 2009 for review). In contrast to the Canidae, the larger species of the Felidae (e.g. leopard, *Panthera pardus*) are more often implicated as livestock predators, apart from caracal *Caracal caracal* and Eurasian lynx (Inskip & Zimmermann, 2009).

In the southern African context, mesopredators – most notably black-backed jackals *Canis mesomelas* and caracal – are claimed to be the dominant predators of livestock (predominantly sheep and goats and to a lesser extent cattle) and valued wildlife species (van Niekerk, 2010; Chapter 3). Several reasons for the relatively large impact of mesopredators on the livestock industry have been suggested (e.g. mesopredator

release; see Chapter 8). However, livestock predation by black-backed jackal and caracal is probably rooted in their ethological and ecological plasticity, which allows them to persist despite centuries of population reduction efforts (Minnie, Gaylard & Kerley, 2016a; Chapter 2). This, in turn, has exacerbated their impacts on the livestock industry.

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In South Africa, humans have been relatively unsuccessful in eliminating the livestock losses caused by black-backed jackals and caracals, despite >350 years of lethal management (Kerley *et al.*, 2017). This may be due to the fact that predation management focuses on reducing mesopredator population size and does not take the ecology and biology of the target predator into account, and may thus produce unexpected population responses (e.g. compensatory reproduction). The effective management of any animal population requires a basic understanding of its biology and ecology (e.g. Knowlton, Gese & Jaeger, 1999) to assist in predicting the responses of these populations to suggested/implemented management plans (Hone, Duncan & Forsyth, 2010; Du Plessis, 2013; Chapter 6).

Developing effective management regimes aimed at reducing predation requires an understanding as to why carnivores attack livestock. Achieving this requires an understanding of the aspects of the carnivores' environment, biology and ecology that predispose them to livestock predation (Breck, 2004). A recent review indicated that there is a general paucity of information regarding the biology and ecology of black-backed jackals and caracals in southern Africa (du Plessis, Avenant & De Waal, 2015). In addition, the existing information is spatially biased, focusing on a subset of South African biomes, and predominantly derived from studies on nature reserves (du Plessis *et*

al., 2015). The dynamic nature of both black-backed jackals and caracals make generalisations across habitats and land uses difficult. This chapter synthesises the available knowledge of black-backed jackal and caracal ecology and biology, and identifies research gaps and opportunities. Additionally, where information is lacking, we make reference to ecological surrogates (e.g. coyote for black-backed jackal, and lynx species for caracal) to highlight the importance of basic biological and ecological research as it relates to adaptive management.

DIET

Resource acquisition plays a fundamental role in influencing carnivore growth, maintenance and reproduction (Fuller & Sievert, 2001). Various factors influence the ability of carnivores to obtain appropriate resources to sustain these vital processes, including inter- and intraspecific competition (Leo, Reading & Letnic, 2015), local environmental conditions (Sacks, 2005), and availability, abundance and dispersion of resources (Todd & Keith, 1983; Klare, Kamler, Stenkewitz & MacDonald, 2010). In addition, anthropogenic habitat modifications such as habitat reduction and fragmentation, as well as predator management (lethal and non-lethal) may further augment the functional responses of carnivore diets to local environmental conditions (Benson, Mahoney & Patterson, 2015). The

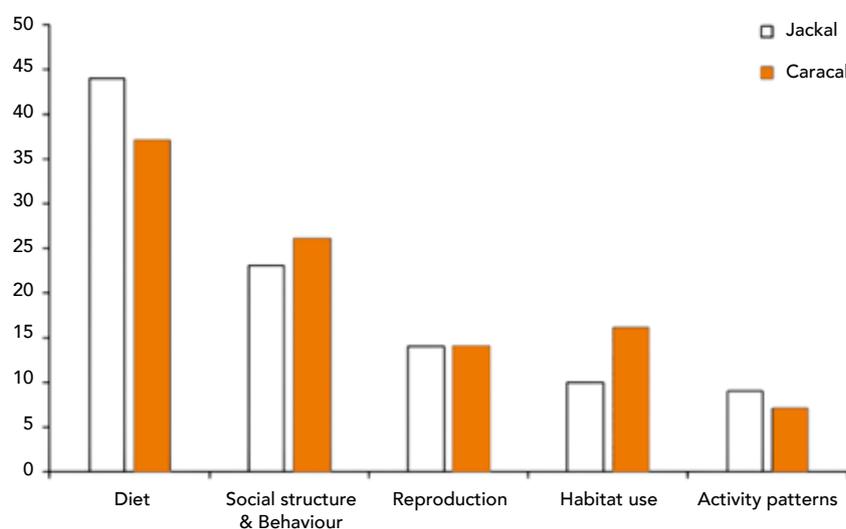


Figure 7.1. The proportion of research (peer-reviewed publications, theses and dissertations) conducted on the biology and ecology of black-backed jackals (n = 58) and caracals (n = 29) between 1960 and 2013 (adapted from du Plessis *et al.*, 2015).

diet of black-backed jackals and caracals is the most widely studied part of their biology and ecology (Figure 7.1), which is not surprising given their role as livestock predators.

Black-backed jackal

Until recently (see prey selection below), black-backed jackals, like other small- to medium-sized canids (e.g. dingo, Allen & Leung, 2014; coyote, Murray *et al.*, 2015), were considered generalist omnivores, with a catholic diet that varies according to local food availability (Loveridge & MacDonald, 2003; Kok & Nel, 2004; Fourie, Tambling, Gaylard & Kerley, 2015). The diet is dominated by small- to medium-sized mammals, and is often supplemented with birds, reptiles, carrion, invertebrates and fruit (Brassine & Parker, 2012; Kamler, Klare & MacDonald, 2012a; Morwe, 2013; van de Ven, Tambling & Kerley, 2013; Minnie, 2016). Hayward *et al.*, (2017) reported that black-backed jackals may have evolved to optimally prey on small- and medium-sized mammals. This is substantiated by the predominance of small- and medium-sized mammals in their diet, irrespective of location and season (Kaunda & Skinner, 2003; Brassine, 2011; Morwe, 2013; van de Ven *et al.*, 2013).

However, when small- and medium- size mammals become rare, black-backed jackals, like other canids, may consume a wider variety of food items (i.e. wider niche breadth) to maintain energy intake (Kaunda & Skinner, 2003). This has also been documented in coyotes (Gese, Ruff & Crabtree, 1996) and dingoes (Corbett & Newsome, 1987); when carcass availability was reduced, subordinate individuals were out-competed by dominant individuals and were forced to prey on small mammals. Additionally, black-backed jackals have been shown to prey extensively on the young of hider species (i.e. neonates hidden in the vegetation; Klare *et al.*, 2010). This results in seasonal fluctuations in the consumption of ungulate species, with neonates of hider species being consumed more in the lambing season (Klare *et al.*, 2010; Morwe, 2013). Therefore, black-backed jackals have the ability to modify their diet in response to variations in resource availability. Opportunistic feeding and dietary flexibility, amongst other factors, are suggested as causative factors in the persistence of black-backed jackal populations despite concerted



Black-backed jackal *Canis mesomelas*. Photo: Colin Grenfell.

population reduction efforts (Grafton, 1965).

Atkinson, Rhodes, Macdonald & Anderson (2002) found that black-backed jackals follow an optimal foraging pattern which allows them to opportunistically access spatially and temporally variable resources. Black-backed jackals are cursorial predators and during foraging, they typically consume the first food source encountered (Kok & Nel, 2004). Additionally, they may also access larger prey species by predation on their neonates, or this may be facilitated by group hunting and also by scavenging from apex predator kills (see resource provisioning by apex predators below). Black-backed jackals generally hunt singularly or in pairs, but may occasionally hunt in groups to improve the prospects of capturing larger prey (Moehlman, 1987; McKenzie, 1990). For example, black-backed jackals in Botswana formed temporary “packs” of six to 12 individuals to attack and kill an adult impala (McKenzie, 1990); and in Namibia they displayed similar co-operative hunting to kill an adult springbok *Antidorcas marsupialis* (Krofel, 2008).

Given their opportunistic feeding behaviour, black-backed jackals, like other canids, show intraspecific variation in diet in accordance with local resource abundance and dispersion (Macdonald & Sillero-Zubiri, 2004; Drouilly, Natrass & O’Riain, 2018). For example, the diet of black-backed jackals on reserves in arid and semi-arid areas is dominated by small antelope (Brassine, 2011; Kamler *et al.*, 2012a; van de Ven *et al.*, 2013; Fourie *et al.*, 2015; Minnie, 2016). Conversely, black-backed

jackal diet in more mesic areas is dominated by small mammals accompanied by an associated decrease in the consumption of antelope species (Rowe-Rowe, 1983; Kaunda & Skinner, 2003). However, few studies quantify the dietary shifts of black-backed jackals between areas with heterogeneous resource availability (*cf.* Drouilly *et al.*, 2018).

Diet shifts in black-backed jackals may occur when alternative resources are provisioned. Various factors may influence the type and amount of resources available to black-backed jackals. In South Africa, the most pertinent variation in prey occurs between various land uses. Black-backed jackal diets differ considerably between agricultural and natural habitats (Drouilly *et al.*, 2018). This may be due to dietary shifts in response to resource provisioning. Here, we contrast the diet of black-backed jackals in natural systems – which include carcass provisioning by apex predators – and livestock farms – which include livestock provisioning.

Resource provisioning by apex predators

Given the black-backed jackal's reputation as a scavenger, the influence of carcass provisioning by apex predators has been widely investigated in South Africa. However, there is disagreement as to whether the provisioning of carcasses actually influences black-backed jackal diet. Some authors suggest that this is not the case (e.g. Brassine & Parker, 2012; Yarnell *et al.*, 2013), whereas others show that black-backed jackals consume larger prey species in the presence of apex predators (e.g. van der Merwe *et al.*, 2009b; Fourie *et al.*, 2015; Minnie, 2016). This suggests that scavenging from carcasses may be context-dependent and varies according to local resources and possibly the species of apex predator involved.

The presence of apex predators may also negatively affect black-backed jackal populations through predation (*i.e.* interspecific competition), and the continuum between facilitation and competition may be related to apex predator density and the species involved. For example, at low wolf *Canis lupus* densities, smaller wolf packs leave larger portions of a kill unconsumed thereby providing more scavenging opportunities for wolverines *Gulo gulo*, with the converse holding at high wolf densities (Khalil, Pasanen-Mortensen & Elmhagen, 2014). Therefore, in reserves with low densities of apex

predators, facilitation may play a more important role than competition resulting in resource provisioning (Minnie, 2016), but this also depends on how the carnivores partition the habitat. Given the context-dependent nature of black-backed jackal foraging behaviour and the contrasting results obtained in various studies, more research is required to estimate how black-backed jackal diets vary in response to varying densities of apex predators (*i.e.* facilitation *versus* competition).

Resource provisioning by humans

The availability of livestock, especially small breeds, will undoubtedly affect black-backed jackal diets. Due to domestication, sheep and goats have lost some of their anti-predator responses (but see Shrader, Brown, Kerley & Kotler, 2008), and are managed in rangelands with limited predation refuges. Black-backed jackals, like caracals, successfully attack and kill livestock. Several dietary studies conducted on livestock farms indicate that livestock may contribute a large proportion of the diet (25 - 48%; Kamler *et al.*, 2012a), but other studies show that this is not the case (e.g. only 16% of diet; Minnie, 2016). Thus, in pastoral areas, black-backed jackals may shift their diet by including livestock, consuming relatively less indigenous small- to medium-sized ungulates (often the predominant prey on nature reserves; e.g. Minnie, 2016). However, this shift in diet is context-dependent, as several studies show that black-backed jackals on farms consume more small mammals and small ungulates than on nature reserves (Bothma, 1971a; Minnie, 2016). This suggests that black-backed jackals may prefer natural prey over livestock (Table 7.1), but this is not always the case (e.g. Central Karoo, South Africa; Drouilly *et al.*, 2018). It has been hypothesised that abundant natural prey may buffer livestock losses (Avenant & Du Plessis, 2008; Hayward *et al.*, 2017; Nattrass, Conradie, Drouilly & O'Riain, 2017). Such buffering has been documented for coyotes, where a reduction in indigenous prey led in an increase in livestock predation (Stoddart, Griffiths & Knowlton 2001). Thus, maintaining a healthy natural prey base may reduce predation on livestock, but this hypothesis has not been tested for black-backed jackals.

Table 7.1. Prey preferences of black-backed jackals, indicating if prey is significantly avoided, consumed in accordance with abundance, or significantly preferred (extracted from Hayward *et al.*, 2017). The asterisk (*) indicates estimated avoidance.

Prey species				Prey species			
	Avoided	In accordance	Preferred		Avoided	In accordance	Preferred
Aardwolf				Reedbuck, mountain			
Birds				Rodents			
Blesbok				Sable	*		
Buffalo				Small mammals			
Bushbuck				Springbok			
Bushpig				Springhare			
Duiker, common				Steenbok			
Eland				Suids			
Elephant	*			Tsessebe	*		
Gemsbok				Warthog			
Giraffe	*			Waterbuck			
Hare, Cape				Wildebeest, black			
Hares				Wildebeest, blue			
Hartebeest, red				Zebra, plains			
Impala							
Kudu				Domestic prey:			
Lagomorphs				Cattle	*		
Nyala	*			Goat	*		
Ostrich	*			Livestock			
Reedbuck, common	*			Sheep			

Prey preference

Although black-backed jackals may alter their diets in response to resource fluctuations, they do display prey preferences (Hayward *et al.*, 2017). A recent study compared the prey preferences of black-backed and golden jackals and found that black-backed jackals prefer to consume birds, common duiker *Sylvicapra grimmia*,

bushbuck *Tragelaphus scriptus* and springbok (Table 7.1), and prefer to prey on species with an average (3/4 adult female body mass) body mass of 21.7 ± 3.5 kg (range: 14 - 26 kg; Hayward *et al.*, 2017). In general, black-backed jackals prefer to prey on natural prey, whilst consuming livestock in accordance with abundance, i.e. there is no

evidence that livestock are preferred prey (Table 7.1; Hayward *et al.*, 2017).

It is worth noting that black-backed jackal dietary descriptions or analyses do not provide information on the impact on the livestock- and game farming industries,

Caracal

Caracals are generalist predators, but have a more specialized diet than black-backed jackals (Kok & Nel, 2004; Melville, Bothma & Mills, 2004; Braczkowski *et al.*, 2012; Pohl, 2015; Jansen, 2016). Although mammals dominate their diet, they may consume birds, reptiles, invertebrates, fruit and seeds, and vegetation (Palmer & Fairall, 1988; Avenant & Nel, 2002; Melville *et al.*, 2004; Braczkowski *et al.*, 2012; Jansen, 2016). Caracals predominantly prey on small- to medium-sized mammals ranging in size from rodents to ungulates (up to about 50 kg; Pohl, 2015). The prey base of caracals is similar to that of black-backed jackals (Drouilly *et al.*, 2018), suggesting that these two species may compete when they occur in sympatry (Pringle & Pringle, 1979). However, no research on resource partitioning has been conducted.

Caracals may use one of two strategies to access prey: 1) a patch selection strategy may be employed when moving directly between areas (patches) where food is abundant (Stuart, 1982 ; Avenant & Nel, 1998; Melville & Bothma, 2006), or 2) when prey abundance is relatively low, caracals may employ a random foraging strategy where they move through their range and consume food as it is encountered (Avenant & Nel 1998; van Heezik & Seddon 1998; Melville & Bothma, 2006). Caracals usually prey on the most abundant prey species (Avenant & Nel, 1997; Avenant & Nel, 2002) but, like black-backed jackals, are capable of switching prey in response to spatial and temporal fluctuations in resource abundance and dispersion, albeit to a lesser extent (Drouilly *et al.*, 2018). In the driest parts of southern Africa, caracals predominantly consume mammals (Grobler 1981; Melville *et al.*, 2004; Pohl, 2015), whereas in more mesic areas the consumption of alternate prey items, particularly birds, increases (e.g. Cape Peninsula, Western Cape Province, South Africa, Leighton, G. pers. comm.). Seasonal variation in mammalian prey consumption has also been noted for caracals, where they consumed more springbok when caracal females were lactating or provisioning kittens (Avenant & Nel,

nor do they differentiate between prey that is killed and or scavenged. This would require the identification and quantification of prey killed by black-backed jackals (Chapter 3).



Caracal *Caracal caracal*. Photo: Colin Grenfell.

1997; 1998; 2002). Further, the occurrence of sympatric carnivore remains (e.g. black-backed jackals) in caracal scats is not unusual (Palmer & Fairall, 1988; Avenant & Nel, 1997; Avenant & Nel, 2002; Melville, 2004; Braczkowski *et al.*, 2012). Melville *et al.*, (2004) ascribed the presence of carnivores in caracal diet to a low density of ungulate prey, and the prospect of intraguild predation needs to be further explored. This does, however, further highlight the opportunistic feeding by caracal.

Resource provisioning by humans

Similar to black-backed jackals, diet shifts may occur when alternative resources are provisioned. However, caracals rarely scavenge (Mills, 1984; Avenant, 1993; Nowell & Jackson, 1996), although scavenging was documented in Etosha National Park where a caracal scavenged on a springbok killed by a cheetah *Acinonyx jubatus* (Nowell & Jackson, 1996) and in the Central Karoo where caracals scavenged on sheep and a kudu (Drouilly *et al.*, 2018). Thus, in contrast to black-backed jackals, resource provisioning by apex predators appears to be of little importance. The diet of caracals differs with land use, with caracals on livestock farms supplementing their diet with livestock (Pringle & Pringle, 1979;

Skinner, 1979; Stuart, 1982; Avenant & Nel, 2002; Kok & Nel, 2004; Melville *et al.*, 2004; Drouilly *et al.*, 2018), particularly during the livestock lambing season (Pohl, 2015), or when a female caracal is lactating, or accompanied by young (Avenant, 1993; Avenant & Nel, 1998). However, despite this livestock provisioning by humans, small mammals such as lagomorphs and rock hyraxes *Procavia capensis* constitute an important part of their diet (Grobler, 1981; Melville *et al.*, 2004; Pohl, 2015; Jansen, 2016). For example, on livestock farms in the Bedford district, Eastern Cape Province, caracals fed predominantly on wild prey (Pringle & Pringle, 1979), and on the farms surrounding the West Coast National Park, Western Cape Province, predation on livestock increased when the abundance of rodents decreased (Avenant & Nel, 1997; 1998; 2002). This suggests that, as suggested for black-backed jackals, caracals prefer to prey on natural prey and abundant natural prey may buffer livestock losses.

Prey preference

Although most studies indicate that caracals prey predominantly on small- to medium-sized mammals, few studies have quantified prey consumption relative to prey availability, which is essential in estimating prey preference. Several studies have shown that caracals are non-selective, consuming the prey with the highest abundance (Moolman, 1984; Avenant & Nel, 2002). However, two localised studies indicated that caracals prefer to prey on rock hyraxes, rodents and lagomorphs (Jansen, 2016; Drouilly *et al.*, 2018), and that preference for medium-sized ungulates such as common duiker, steenbok *Raphicerus campestris* and springbok varies depending on location. Similar to black-backed jackals, caracals on farms avoided sheep and goats and preferred to prey on natural prey (Jansen, 2016), providing additional support for the hypothesis that abundant natural prey may buffer livestock losses. However, more research relating prey abundance to prey consumption is required to determine the prey preferences of caracals across South Africa.

The available dietary information on caracals indicates that they are generalist and opportunistic predators that may include livestock in their diet. However, there is some evidence that they prefer to prey on natural prey and consume relatively less livestock than black-backed

jackals (Jansen, 2016; Drouilly *et al.*, 2018). Although the diet of caracals has been studied more than any other aspect of its ecology (Figure 7.1), most studies have been conducted in protected areas (see du Plessis *et al.*, 2015 for review). Thus, more research is required to determine the diet of caracal on livestock and game farms, as well as its impact on the livestock and game ranching industries.

SOCIAL STRUCTURE AND REPRODUCTION

Black-backed jackal

Black-backed jackals have a complex social structure. In a stable social system, black-backed jackals are monogamous (Moehlman, 1987). Pair formation may increase hunting success (Lamprecht, 1978) and is critical for territorial defence and the successful rearing of pups (Moehlman, 1987). However, the social structure of black-backed jackals is flexible and may consist of family groups ranging from one to eight individuals (Rowe-Rowe, 1978; Rowe-Rowe, 1982). Family groups generally comprise a mated territorial pair and their offspring (Ferguson, Nel & de Wet, 1983; Loveridge & MacDonald, 2001). However, some groups may also contain older sub-adults that have delayed dispersal to act as helpers in raising sibling offspring (Moehlman, 1979; Rowe-Rowe, 1982; Ferguson *et al.*, 1983). This is expected to occur under conditions where food availability is high (Ferguson *et al.*, 1983). Additionally, the territorial pair may tolerate subordinate individuals on the fringes of their territories (i.e. floaters, Ferguson *et al.*, 1983) and cases have been documented where black-backed jackals allowed other mated pairs, sub-adults or juveniles into their territories (MacDonald, 1979; Rowe-Rowe, 1982; Ferguson *et al.*, 1983; Hiscocks & Perrin, 1988; McKenzie, 1990; Oosthuizen *et al.*, 1997; Loveridge & MacDonald, 2001; Loveridge & MacDonald, 2003). Such relaxation in territorial defence may occur when resources are locally abundant (see Box 7.1).

The dominant mated pair typically defends an exclusive breeding territory and prevents younger subordinates from reproducing (Loveridge & Nel, 2004). However, extra-pair reproduction has been recorded and has been attributed to anthropogenic mortality (McKenzie, 1993; Walton & Joly, 2003). Polygamy – as a mechanism to compensate for high mortality (e.g.

coyote; Kleiman & Brady, 1978) – may counter lethal management aimed at reducing black-backed jackal population size by allowing more females to reproduce to compensate for increased mortality (see Box 7.2).

Mating peaks during the winter months (Skead, 1973), but late autumn and early spring matings have also been recorded (Stuart, 1981). Gestation lasts for about two months but may extend up to 70 days (Bernard & Stuart, 1992; McKenzie, 1993; Walton & Joly, 2003). Parturition usually occurs from winter to early spring (Bothma, 1971b; Bernard & Stuart, 1992; McKenzie, 1993). Additionally, parturition at a regional level may be asynchronous, as breeding pairs may reproduce within one month of each other (Bingham & Purchase, 2002). The timing of the reproductive cycle varies spatially and temporally with local environmental conditions and food availability (Fairall 1968; Rowe-Rowe, 1978; Bernard & Stuart, 1992; McKenzie, 1993; Bingham & Purchase, 2002; Walton & Joly, 2003), as is the case for coyotes (Gese, 2005). Although an earlier onset of reproduction and an extended reproductive period has been linked to increased resource availability (Bernard & Stuart, 1992; Walton & Joly, 2003), little information on the variation in reproductive cycle in response to variation in resources between land uses is available.

Black-backed jackal females have one litter per year,

and litter size ranges between one and nine, depending on the female's body condition (Minnie *et al.*, 2016a), social status (Loveridge & Nel, 2013), and anthropogenic mortality (see Box 7.2; Minnie *et al.*, 2016a). Both parents help raise the pups, which remain in the den from August to November (Ferguson *et al.*, 1983). However, as with most aspects of black-backed jackal ecology, variation in this basic pattern occurs, as pups have been recorded in dens from January to July (Ferguson *et al.*, 1983). Pups emerge from the natal den after approximately three weeks and are weaned at eight to nine weeks of age. They start foraging with their parents at three months of age, but they remain in close proximity (ca. 2 km) to the natal den until six months of age (Ferguson *et al.*, 1983; Moehlman, 1987). It is only when they get older (ca. seven months) that immature black-backed jackals start moving longer distances (see section on Dispersal).

Black-backed jackals become sexually mature at 11 months and young black-backed jackals can either: 1) become helpers (approximately one third of the litter), which aid in the raising, provisioning and guarding of subsequent litters, or 2) disperse (approximately two-thirds of the litter) from their natal range in search of mates and territories (Ferguson *et al.*, 1983; Moehlman, 1987). Families with helpers have significantly higher offspring survivorship (Moehlman, 1979).

Box 7.1 Influence of clumped, high density resources on social structure

Local resource richness and dispersion may alter carnivore spatial organisation and social structure. This should be particularly pronounced for scavenging species. Thus, given the fact that caracals rarely scavenge (see Diet), we do not expect variation in social structure in response to high-density resources. However, as home range is partly determined by resource availability, caracal density may increase when resources are locally abundant (see Home range). However, no research on the variation in caracal social structure in response to variation in resource density has been conducted. Further research is needed to determine if increased prey availability (e.g. livestock) results in a reduction in home range size and a consequent increase in population density.

Conversely, in certain instances, black-backed jackals have displayed a collapse in their typical exclusive territorial structure, which may be driven by an increase in local resource abundance. This is exemplified by variation in territory size and group size at Cape fur seal *Arctocephalus pusillus* colonies in Namibia. Here, tremendous variation in resource abundance occurs, with very high prey densities on the coast and low prey densities inland (Jenner, Groombridge & Funk, 2011). Inland,

black-backed jackals display the normal mutually exclusive territorial structure. Jenner *et al.*, (2011) reported that black-backed jackals defend these low prey density areas to maintain exclusive space to raise offspring successfully. Consequently, black-backed jackal group size is relatively small and territory size is relatively large. In contrast, at seal colonies where local resource abundance is relatively high, this territorial structure of black-backed jackals collapses, resulting in territorial overlap (Hiscocks & Perrin, 1988), increased group size and relatively small home ranges (Jenner *et al.*, 2011; Nel, Loutit, Braby & Somers, 2013).

Therefore, a local increase in resource abundance (e.g. livestock, open carcass dumps, and large animal carcass) will likely produce similar patterns as those observed at Namibian seal colonies – i.e. increased local abundance and population densities, and reduced territory size. Increased black-backed jackal densities have been documented around waterholes, antelope carcasses (Ferguson *et al.*, 1983) and at vulture restaurants (Yarnell, Phipps, Dell, MacTavish & Scott, 2015). Similar population-level responses to anthropogenic resource subsidies have been documented for several carnivores (see Newsome *et al.*, 2015 for review). Further, this may have important consequences for predation on economically important prey such as livestock and valued wildlife species, which represent “clumped resources”. For example, Yom-Tov *et al.*, (1995) found that illegal garbage dumps around informal human settlements (which included dead poultry and livestock) resulted in an increase in golden jackal population size. This, in turn, resulted in increased local predation on cattle calves.

Caracal

Caracals display the typical solitary social structure of other felids (e.g. leopard and lynx spp.), where the territory of a male may overlap with several females (Avenant, 1993; see Home range). Thus, males and females only come together to reproduce. Only females partake in parental care and family groups thus consist of an adult female and her offspring. This structure has been reported throughout their distributional range, with little variation. This suggests that caracals, unlike black-backed jackals, do not display a flexible social structure.

Unlike black-backed jackals, caracals can reproduce throughout the year. The oestrous cycle of the female is about 14 days with the oestrous period lasting three to six days (Stuart, 1982; Bernard & Stuart, 1987). The female may mate with several males (polygamy) and mating order is determined by the body mass and age of the males (Weisbein & Mendelssohn, 1989). The gestation period ranges from 78 to 81 days (Bernard & Stuart, 1987). Parturition occurs throughout the year, but peaks (74% of births) between October and February in southern Africa (Bernard & Stuart, 1987).

The fact that caracals are reproductively active throughout the year suggests that reproduction is predominantly determined by resource availability. Females need to attain an appropriate body condition

to reproduce successfully. In environments with seasonal fluctuations in resource availability, female body condition is expected to be lower at the end of winter, resulting in peak parturition in summer (Bernard & Stuart, 1987). This may coincide with the reproductive cycle of their main prey species (see Diet). Additionally, caracals feeding on livestock, which represents an aseasonal resource, may maintain a relatively high body condition throughout the year allowing them to give birth throughout the year (Bernard & Stuart, 1987). Research on Canadian lynx *Lynx canadensis* indicate that during periods of high prey availability, young females remained in or close to their natal range where they successfully reproduced (Slough & Mowat, 1996), increasing the proportion of pregnant females in the population. If a similar case exists in caracals, the presence of livestock may result in increased densities and reproduction, which may further exacerbate livestock losses. However, no research on the reproductive response of caracals to prey base variation has been conducted.

Litter size typically ranges between one and three kittens, averaging 2.2 kittens per litter (Bernard & Stuart, 1987), although litters as large as six have been reported (Weisbein & Mendelssohn, 1989). Kittens are weaned between 15 and 24 weeks of age. Bernard & Stuart, (1987) estimated that caracals reach sexual maturity

between seven and 10 months of age, after which reproduction of the caracal, as is the case for the black-caracals disperse from their natal range (see Dispersal). backed jackal (see Box 7.2), and thus warrants future It is unclear if anthropogenic mortality influences the research.

Box 7.2 Reproductive responses to anthropogenic mortality

The lethal management of carnivores to reduce population size and the associated livestock losses may have significant impacts on reproduction. This may result in compensatory reproduction – which is an increase in reproductive output to compensate for increased mortality – that may manifest as increased litter size, larger proportion of breeding females, increased reproductive lifespan, or a decrease in age at first reproduction.

Compensatory reproduction in caracal is unknown, but presumably can occur, as it has been reported for the Canadian lynx (Parker, Maxwell, Morton & Smith, 1983) and Eurasian lynx (Bagraade *et al.*, 2016). The higher number of kittens could lead to a rapid population recovery after population reductions. It is further argued that an increase in population densities due to compensatory breeding may result in predators feeding exclusively on livestock and introduced wildlife due to their availability (du Plessis *et al.*, 2015). However, almost no research (*cf.* Brand, 1989) on the effects of lethal management on caracal reproduction has been done. It is important to determine the reproductive responses of caracals to lethal management to determine the effectiveness of these techniques in managing livestock predation.

In canids, compensatory reproduction has been documented for red foxes (Harris & Smith, 1987; Cavallini & Santini, 1996), coyotes (Knowlton, 1972; Sterling, Conley & Conley, 1983) and side-striped jackals (*Canis adustus*; Bingham & Purchase, 2002), but not dingoes (Allen, Higginbottom, Bracks, Davies & Baxter, 2015; Allen, 2015). This has also recently been documented for black-backed jackals in South Africa in response to lethal management (Minnie *et al.*, 2016a). On livestock and game farms where black-backed jackals are lethally managed, younger individuals showed an increased pregnancy rate in conjunction with larger litters (Minnie *et al.*, 2016a). This was attributed to a release in density-dependent population regulation and social dominance (due to anthropogenic mortality) from dominant individuals, which usually prevent subordinates from reproducing. Additionally, a reduction in population density may result in an increase in resource availability for the remaining individuals, thereby allowing subordinate individuals to attain a better body condition thus facilitating reproduction (e.g. coyote; Knowlton *et al.*, 1999). This increased reproductive output may result in the rapid recovery of populations to pre-management densities, thereby negating population reduction efforts. However, these findings are based on a single study in the Karoo (Eastern and Western Cape Provinces), making generalisations across habitats difficult. More research investigating the reproductive responses of black-backed jackals in conjunction with estimates of population size pre- and post-management interventions is required.

ACTIVITY PATTERNS

Black-backed jackal

The information on black-backed jackal activity patterns is scant, with less than 10% of research focusing on this aspect (Figure 7.1; du Plessis *et al.*, 2015). Black-backed jackals may be active during any part of the day (Walton & Joly, 2003), but activity tends to peak during sunrise and sunset (i.e. crepuscular; Kaunda, 2000). For example, in Botswana, black-backed jackals were predominantly active between 17h00 and 22h00 and between 05h00 and 08h00, with peaks in activity occurring around 18h00 and 06h00 (Kaunda, 2000). Black-backed jackals in the Kgalagadi Transfrontier Park, Northern Cape Province, also showed a crepuscular activity pattern, but these peaks occurred between 17h00 and 21h00 and between 05h00 and 09h00 (Ferguson, Galpin & de Wet, 1988). The timing and onset of these activity peaks seem to vary depending on local conditions, and may be due to several factors.

It has been suggested that the activity of black-backed jackals closely follows that of their main prey species (Ferguson *et al.*, 1988; Hiscocks & Perrin, 1988; Kaunda, 2000; Walton & Joly, 2003). In the North-West Province, black-backed jackal activity closely mirrored the peak foraging time of their main rodent prey species on both farms and reserves (Ferguson *et al.*, 1988). Black-backed jackals foraging at seal colonies do not display pronounced activity peaks, as they are able to utilise the resource at any given period (Hiscocks & Perrin, 1988). However, the activity patterns of black-backed jackals are not always influenced by the activity of their main prey (e.g. Loveridge & MacDonald, 2003). Apart from a few studies in isolated locations, the activity patterns of black-backed jackals have rarely been compared to that of their prey, and this warrants further investigation. This may be particularly important in livestock farming areas, and may direct livestock management practices outside of black-backed jackal activity peaks.

Seasonal variation in activity also occurs, as black-backed jackal activity increases during the winter mating season (Ferguson, 1980). This seasonal variation in activity also corresponds to the seasonal variation in sunset and sunrise times. This is not surprising, as visual predators require sufficient ambient light to successfully capture prey. Black-backed jackals in Zimbabwe were reported

to be more active diurnally, which may be due to better light conditions for hunting and predator avoidance (Loveridge & MacDonald, 2003). Similar to coyotes (Lehner, 1976), black-backed jackals may have evolved a visual system designed for crepuscular activity. This suggests that black-backed jackals should be relatively more active during full moon when light conditions are conducive to hunting. However, Ferguson *et al.*, (1988) showed that this is not the case and ascribed this to the prey easily spotting and avoiding black-backed jackals during full moon periods. Nocturnal light conditions may have important consequences for livestock predation. Lehner (1976) suggested that during nocturnal periods of low ambient light (e.g. new moon), livestock may provide more visual cues (owing to white colouration) for coyotes than natural prey, which may lead to increased livestock predation. However, this has not been investigated for black-backed jackals.

Interspecific competition may also influence black-backed jackal activity. Apart from facilitation (see diet), apex predators (e.g. leopard) also attack and kill black-backed jackals. The intensity of facilitation and competition may affect the activity patterns of mesopredators, which in turn, may depend on the density of apex predators (Newsome *et al.*, 2017; Chapter 8). Additionally, niche partitioning between black-backed jackals and side-striped jackals exists (Loveridge & MacDonald, 2003). In most parts of South Africa, black-backed jackal and caracal are sympatric, yet little information on niche partitioning between these two species exists.

Human activities, particularly lethal management, also modify the activity patterns of black-backed jackals. In areas where black-backed jackals are heavily persecuted, they are more active at night (Rowe-Rowe, 1978; Ferguson *et al.*, 1988; Hiscocks & Perrin, 1988; Fuller, Biknevicius, Kat, Valkenburgh & Wayne, 1989). With the prevalence of call-and-shoot night hunting (Chapter 6), it is speculated that black-backed jackals may become more diurnal to avoid dangerous periods. However, more information on the responses of black-backed jackals to lethal and non-lethal management is required. This will provide valuable insights in designing effective adaptive management programmes aimed at reducing predation on livestock and valued wildlife species.

Caracal

Despite the importance of caracals as predators of livestock, little is known about their activity patterns and the factors that influence them, and only two studies have investigated this in southern Africa (Figure 7.1; du Plessis *et al.*, 2015). Caracals have been described as being mostly nocturnal, but much variation in activity patterns exists across their range (Skinner, 1979; Stuart, 1982). In the West Coast National Park, Western Cape Province, caracals were active during the night, but also during cooler winter days ($\leq 22^{\circ}\text{C}$, Avenant & Nel, 1998). Both diurnal and nocturnal activity has been reported throughout their range. In Turkey, caracals were active during the day and night except for late morning and around midnight (İlemin & Gürkan, 2010). In Yemen, caracals were more active during the day (Khorozyan, Stanton, Mohammed, Al-Ra'il & Pittet, 2014), while they were more active late at night and during crepuscular hours in India (Singh, Qureshi, Sankar, Krausman & Goyal, 2014). Sexual variation in activity is also evident, with males being active for longer periods and moving longer distances than females. This may be due to males having larger territories to patrol (see Home range; Avenant & Nel, 1998).

Various factors influence caracal activity patterns. Several studies have indicated that rain, moon phase and wind speed do not affect activity (Moolman, 1986; Brand, 1989; Avenant & Nel, 1998). However, it has been suggested that activity may be influenced by light intensity and temperature. For example, caracals were active for longer periods on colder nights ($< 20^{\circ}\text{C}$, Avenant & Nel, 1998). Light intensity in combination with temperature may also impact activity, as males increased diurnal activity during overcast periods when ambient temperatures were between 20 and 22°C (Avenant & Nel, 1998). Diurnal hunting has also been documented when the weather is cool and overcast (Skinner, 1979). In Israel, caracals were largely nocturnal, but displayed seasonal variation in diurnal activity, depending on temperature and the activity patterns of their prey (Weisbein & Mendelssohn, 1989).

The activity patterns of caracals may mirror the activity of their main prey, but little information on this is available. However, prey size has been shown to influence activity patterns. When caracals kill larger prey (e.g. springbok) they may feed on the carcass for a few

days (Avenant & Nel, 1998). Therefore, periods of high activity linked to foraging on smaller prey (e.g. rodents and lagomorphs) may be interspersed with periods of low activity linked to the consumption of larger prey.

Caracal activity patterns are therefore context-dependent and vary with biotic and abiotic factors. They are also likely to be impacted by the intensity of human activities, especially in areas where caracals are persecuted (Ramesh, Kalle & Downs, 2016a). This may be particularly important, as spotlight hunting is used to manage caracal populations on livestock farms (Chapter 6), and may result in increased diurnal activity.

HOME RANGE AND HABITAT SELECTION

Black-backed jackal

Home range

Home range sizes of black-backed jackals vary considerably (Table 7.2), with ranges between 1 – 30 km² being reported. For example, in KwaZulu-Natal Province, average home range size varies between 6 km² (Humphries, Ramesh, Hill & Downs, 2016) and 18 km² (Rowe-Rowe, 1982) whereas in the Kalahari, Northern Cape Province, home range size varies between 2 and 5 km². In Zimbabwe, home range size varies between 0.3 and 1.3 km² (Loveridge & MacDonald, 2001), and in Namibia this ranges between 20 and 30 km² (Hiscocks & Perrin, 1988). Variation in black-backed jackal home range size may be attributed to variation in food availability and dispersion. For example, Ferguson *et al.*, (1983) showed that in areas with high prey density (e.g. abundant small mammals) black-backed jackal home range was smaller relative to areas with low prey density (see Box 7.1).

Home range size may also vary seasonally, but is unlikely to be related to seasonal variation in resources availability (Rowe-Rowe, 1982). Seasonal variation in home range size is related to the reproductive cycle, with home ranges being larger during the mating season and smaller during the whelping season (Loveridge & MacDonald, 2001). Humphries *et al.*, (2016) also documented seasonal variation in home range size in agricultural areas in the KwaZulu-Natal Province, but this was attributed to social status and was based on a small sample size. Conversely, research on coyotes in modified

Table 7.2. Mean home range, with the number of individuals tracked in parentheses (n), of male and female black-backed jackals. Only a selection of references were used to illustrate variation in home range size between various regions and land uses. MCP: Minimum Convex Polygon; FK: Fixed Kernel.

Study area	Country	Protected area	Mean home range in km ² (n)		Method	Reference
			Male	Female		
Free State Province, Benfontein Game Farm	South Africa	No	17.75 (6)	-	MCP	Kamler, Stenkewitz, Klare, Jacobsen & Macdonald (2012b)
Gauteng Province, Suikerbosrant	South Africa	No	18.05 (2)	9.5 (5)	MCP	Ferguson <i>et al.</i> , (1983)
KwaZulu-Natal Province, Giant's Castle Game Reserve	South Africa	Yes	18.2 (10)	-	MCP	Rowe-Rowe (1982)
KwaZulu-Natal Province, Midlands	South Africa	No	11.4 (3)	5.6 (1)	FK	Humphries <i>et al.</i> , (2016)
Namib Desert Coast, Cape Cross Seal Reserve	Namibia	Yes	29.95 (2)	20 (2)	MCP	Hiscocks & Perrin (1988)
Namib Desert Coast, Cape Cross Seal Reserve	Namibia	Yes	8.6 (2)	5.5 (2)	Modified MCP	Hiscocks & Perrin (1988)
North West Province, Highveld	South Africa	No	10.6 (8)	-	MCP	Ferguson <i>et al.</i> , (1983)
Northern Cape Province, Kgalagadi Transfrontier Park	South Africa	Yes	4.32 (4)	4.41 (5)	MCP	Ferguson <i>et al.</i> , (1983)

landscapes indicates that there is no seasonal variation in their home range size (Grinder & Krausman, 2001; Gehrt, Anchor & White, 2009; Poessel, Breck & Gese, 2016).

Few studies have compared black-backed jackal home range size between nature reserves and livestock farms. However, the home range size of black-backed jackals on farmlands seems to be larger than those on reserves (Table 7.2), and this may be related to a reduction in natural prey availability on farms (Ferguson *et al.*, 1983). An alternative, but untested hypothesis, is that the home range of black-backed jackals on farms may be smaller than those on reserves, owing to the locally abundant resources (i.e. livestock provisioning). This may result in increased population densities, further exacerbating livestock losses. Thus, more research relating seasonal variation in resource abundance on different land uses to home range size is required.

Owing to the monogamous social structure of black-backed jackals, sexual variation in range size is not apparent among mated pairs, as home ranges of the individuals of a pair overlap completely (Ferguson *et al.*, 1983). Some studies report variation in range size between sexes of single adults (Humphries *et al.*, 2016), whereas other do not (Fuller *et al.*, 1989). However, there is variation in range size among social classes. For example, the home ranges of adults in the Kgalagadi Transfrontier Park, Northern Cape Province and North West Province, were smaller than those of sub-adults. In the Kgalagadi Transfrontier Park adults had an average home range of 11 km² (range: 3 - 22 km²) compared to 85 km² (range: 2 - 575 km²) in sub-adults (Ferguson *et al.*, 1983). Similarly, in farming areas in the North West Province adults had an average home range of 28 km² (range: 3 - 92 km²) compared to 133 km² (range: 1 - 841

km²) in sub-adults (Ferguson *et al.*, 1983). This may be due to subordinate individuals dispersing in search of mates and territories (see Dispersal), whereas dominant pairs are more resident (Ferguson *et al.*, 1983; Humphries *et al.*, 2016).

Home ranges of dominant mated pairs may overlap slightly (less than 10%), but in general other mated pairs are excluded (Ferguson *et al.*, 1983). However, the home ranges of subordinate individuals may overlap extensively with both other subordinates (up to 82%) and dominant pairs (Ferguson *et al.*, 1983). Similar patterns were documented in the KwaZulu-Natal Province where the territories of dominant pairs did not overlap, but there was considerable overlap with the ranges of subordinate individuals (Rowe-Rowe, 1982). Additionally, unmated adults may also show large range overlap with dominant mated pairs (Ferguson *et al.*, 1983).

In general, the home ranges of mated pairs appear to be fixed with little overlap in range with other mated pairs. However, territorial collapse (see Box 7.1) and range shifts (Kaunda, 2000) may occur. Range shifts may occur when a neighbouring pair loses its territory and the dominant pairs expand their territory into the vacant area. This has also been documented for red foxes after the removal of neighbouring groups (Baker, Funk, Harris & White, 2000). However, little information on the benefits and costs of territorial shifts or expansion is available. Removal of territorial jackal pairs through management interventions may prompt this response.

Habitat selection

Black-backed jackals have a wide habitat tolerance and occur in all biomes (Minnie *et al.*, 2016b). Comparatively little research has been conducted on habitat use and selection (Figure 7.1; du Plessis *et al.*, 2015), thus necessitating generalisations across habitats. At a local scale, black-backed jackals select habitats with sufficient food resources (Ferguson, 1980; Kaunda, 2001), shelter from the natural elements, and security from competitors (Kaunda, 2001). In Zimbabwe, black-backed jackals avoid dense vegetation, preferring open grasslands and open woodlands (Loveridge & MacDonald, 2002). This reflects the higher density of preferred prey and improved vigilance opportunities against larger predators in open habitats (Loveridge & MacDonald, 2002). Conversely, in Botswana, black-backed jackals preferred savannah and

bushveld over open grasslands, which was ascribed to the increased availability of food and shelter (Kaunda, 2001). Furthermore, in the Namib Desert – which is characterised by sparse vegetation cover and severe temperature fluctuations – black-backed jackals moved to habitats with sufficient cover against the natural elements (Dreyer & Nel, 1990). Thus, habitat use appears to be driven predominantly by resource availability and habitat structure.

Habitat selection may also be influenced by interspecific competition. For example, black-backed jackals out-compete side-striped jackals for preferred habitats (Loveridge & MacDonald, 2002). Throughout the livestock and game farming areas in South Africa, black-backed jackals and caracals occur in sympatry, and this may influence habitat selection (Ramesh, Kalle & Downs, 2016b). Anecdotal evidence from farmers indicates that black-backed jackal predation is focused on the open plains in the Karoo, in the Eastern and Western Cape provinces, which provides an effective habitat for a cursorial predator. Conversely, caracals keep to the more densely vegetated and mountainous terrain, which provides more cover for an ambush predator. Habitat partitioning between these two predators has not, however, been investigated.

Anthropogenic impacts likely also influence the habitat use and selection by black-backed jackals. It is expected that black-backed jackals should avoid habitats with high human activity (e.g. Kaunda, 2000), or use habitats providing cover for avoiding humans (e.g. golden jackal; Jaeger, Haque, Sultana & Bruggers, 2007). However, this aspect of black-backed jackal ecology has not been investigated.

Caracal

Home range

Sexual variation in home range size is evident, and has been reported in several studies (Table 7.3). Female caracals in the Karoo, Western Cape Province, had smaller home ranges (range: 12 – 27 km²) than males (48 km²; Stuart, 1982). Similarly, Moolman (1986) found that males in Mountain Zebra National Park, Eastern Cape Province, had larger home ranges (15 km²) than females (6 km²). Caracal males are larger than females thus requiring larger home ranges to obtain prey, in addition to finding multiple mates (Melville, 2004;

Table 7.3. Mean home range, with the number of individuals tracked in parentheses (n), of male and female caracals. Only a selection of references were used to illustrate variation in home range size between various regions and land uses. MCP: Minimum Convex Polygon; FK: Fixed Kernel.

Study area	Country	Protected area	Mean home range in km ² (n)		Method	Reference
			Male	Female		
Eastern Cape Province, Cradock	South Africa	No	19.1 (3)	-	-	Moolman (1986)
Eastern Cape Province, Mountain Zebra National Park	South Africa	Yes	15.2 (4)	5.5 (4)	-	Moolman (1986)
KwaZulu-Natal Province, Midlands	South Africa	No	288.47 (1)	44.31 (5)	MCP	Ramesh <i>et al.</i> , (2016a)
KwaZulu-Natal Province, Midlands	South Africa	No	243.10 (1)	40.53 (5)	FK	Ramesh <i>et al.</i> , (2016a)
North-central Namibia	Namibia	No	312.6 (3)	-	MCP	Marker & Dickman (2005)
Northern Cape Province, Kgalagadi Transfrontier Park	South Africa	Yes	308.4 (1)	-	MCP	Bothma & Le Riche (1984)
Western Cape Province	South Africa	No	48 (1)	18.2 (4)	-	Stuart (1982)
Western Cape Province, Langebaan peninsula	South Africa	Yes	26.9 (2)	7.39 (3)	MCP	Avenant & Nel (1998)
Western Cape Province, Stellenbosch	South Africa	No	483 (1)	-	MCP	Norton & Lawson (1985)

Marker & Dickman, 2005; Ramesh *et al.*, 2016a). Therefore, a single male's territory typically overlaps with that of a number of females (Moolman 1986; Avenant 1993; Stuart & Stuart, 2013). Unlike black-backed jackals, in which there is little territorial overlap, the home ranges of caracals overlap both within and between sexes (Moolman, 1986). On the west coast of South Africa, male home ranges almost completely overlapped with those of females (81 – 99%), whereas overlap between females was small (0 - 19%, Avenant & Nel, 1998). Similarly, in Mountain Zebra National Park, Eastern Cape Province, same-sex overlap in home range was small, with female ranges overlapping between 2.5 and 3% and males between 2 and 14% (Moolman, 1986). Similar patterns have been documented for the caracal throughout its distributional range (e.g. in Israel, see

Weisbein & Mendelsohn, 1989).

Variation in home range size is also linked to age and social status, with dispersing sub-adults having larger home ranges than adults. For example, a sub-adult male in the Stellenbosch area, Western Cape Province, initially ranged over 480 km², and then established a much smaller range of 6 km² (Norton & Lawson, 1985). Further, females with kittens have smaller home ranges than single adult females. For example, a female caracal reduced her home range size from 9 km² to 3 km² after parturition and maintained this smaller home range until her kittens reached four months of age (Avenant & Nel, 1998).

Caracal home range size varies according to habitat, with home ranges in arid regions being larger than those in more mesic regions (Table 7.3). In the southern

Kalahari, Northern Cape Province, the home range of an adult male was large (308 km², Bothma & Le Riche, 1984). Similarly, average home range size of males on Namibian farmlands was 316 km² (Marker & Dickman, 2005). However, in more mesic regions, home ranges are smaller. On the Langebaan peninsula, Western Cape Province, males (26 km²) and females (7 km²) had relatively small home ranges (Avenant & Nel, 1998). Similarly, male (65 km²) and female (18 km²) home ranges in the Western Cape Province were much smaller than those reported in arid regions (Norton & Lawson, 1985; Stuart & Wilson, 1988). This variation in home range size along the aridity gradient is probably related to prey availability (Avenant & Nel, 1998), as mesic areas tend to have a higher density of rodent and lagomorph prey.

Seasonal fluctuations in prey availability and dispersion may also translate into seasonal variation in home range size. For example, in Saudi Arabia, a male caracal increased its range from 270 km², during seasons with a high localised prey density, to 1116 km² during seasons with a low prey density (van Heezik & Seddon, 1998). Conversely, in the West Coast National Park, Western Cape Province, seasonal fluctuations in prey availability did not influence home range size (Avenant & Nel, 1998). Thus, home range size in caracal seems to be linked to prey availability, in addition to vegetation cover and abiotic factors (Avenant & Nel, 1998).

Additionally, the range of caracal on reserves may extend onto neighbouring farms, which may result in increased livestock predation on these farms. For example, some caracals in Mountain Zebra National Park, Eastern Cape Province, had their territories confined to the reserve, but others ranged beyond the reserve border (Moolman, 1986). It is unclear how livestock provisioning will affect caracal home range. In some areas it has been suggested that caracals prefer to prey on natural prey (see Diet), thus home ranges may be larger on livestock farms due to reduced density of preferred prey (Moolman, 1986; Marker & Dickman, 2005; Ramesh *et al.*, 2016a). However, the converse may hold if caracals prefer to prey on livestock. This increase in prey densities (i.e. livestock provisioning) may result in a reduction in home range. However, more research on the variation in range size between different land uses with varying prey bases is required.

Habitat selection

Caracals are widespread within South Africa, occurring in all habitat types (Avenant *et al.*, 2016). Similar to black-backed jackals, very little has been published on the habitat selection of the caracal (du Plessis *et al.*, 2015), necessitating generalisations across habitats. In general, the caracal shows a preference for specific habitats in an area, but there is evidence that some individuals may utilise habitats more broadly (Stuart, 1981; Stuart, 1982; Mills, 1984). Caracals are ambush predators, thus habitat selection is driven, in part, by the availability of appropriate cover (Norton & Lawson, 1985). The availability of appropriate prey also affects habitat selection (Moolman, 1986; Avenant & Nel, 1998; van Heezik & Seddon, 1998; Melville, 2004). In an agricultural landscape in the KwaZulu-Natal Province, caracals preferred modified habitats over natural grasslands and forests, which was ascribed to the relatively high availability of rodents and livestock (Ramesh *et al.*, 2016a). Similar patterns have been documented for Iberian lynx *Lynx pardinus*, which vary habitat use in accordance with the level of vegetation cover and prey availability. Iberian lynx preferred natural vegetation, but also selected olive groves and heterogeneous agricultural areas with relatively high densities of preferred prey (Gastón *et al.*, 2016).

Therefore, habitat selection by caracals, like other felids, is likely driven by the availability of suitable vegetation cover (for an ambush predator) and prey. Avenant *et al.*, (2016) suggest that, the mountainous areas may suit caracal more than the plains in the Karoo and Grassland biomes owing to increased vegetation cover. However, little information on the factors driving habitat selection is available and this requires further research. Knowledge about the factors driving habitat selection may allow for the identification of predation "hotspots". For example, Eurasian lynx attacks on livestock were concentrated on 4.5% of the total area where livestock predation occurs (Stahl, Vandel, Herrenschmidt & Migot, 2001), showing that the presence of livestock alone was not sufficient to explain habitat selection. Identifying such "hotspots" may direct livestock management to less risky areas.

DISPERSAL

Black-backed jackal

Dispersal usually occurs between one to two years of age and mainly during autumn and winter (April to September) both on farmlands and protected areas (Ferguson *et al.*, 1983). It is unclear what drives dispersal, but it may be due to intraspecific competition with dominant individuals, and the need to establish a territory, find food and a mate and reproduce (Loveridge & MacDonald, 2001; Minnie *et al.*, 2016a). Loveridge & Macdonald (2001) suggested that dispersing black-backed jackals may have one of four options depending on the local conditions: (1) stay in their natal territory as a helper; (2) move into vacant territories; (3) move into nearby territories to be incorporated into those territories' resident groups; or (4) float between their natal territory and adjacent territories.

Black-backed jackals have the ability to disperse over long distances, as dispersal in excess of 100 km has been reported across several habitat types in South Africa (Bothma, 1971b; Ferguson *et al.*, 1983; Humphries *et al.*, 2016; Minnie, Zalewski, Zalewska & Kerley, 2018). Black-backed jackals appear to have few absolute dispersal barriers, as tarred roads, railway tracks, rivers and fences (including electrified "predator-proof" fences) are frequently crossed (Ferguson *et al.*, 1983; Minnie *et al.*, 2018). However, the permeability of these potential barriers varies (Minnie *et al.*, 2018). The ability of black-backed jackals to cover large distances without being hampered by fences suggests that management aimed at reducing local population size may be counteracted by immigration from other populations (Minnie *et al.*, 2018).

In areas where hunting intensity varies across the landscape (e.g. livestock- and game farms *versus* nature reserves), black-backed jackals disperse from lightly managed or unmanaged reserves into heavily managed farms (Minnie *et al.*, 2016a; 2018). This is driven by the fact that lethal management disrupts the mutually exclusive social structure, which results in vacant territories on livestock and game farms where jackal are lethally managed. Thus, black-backed jackals disperse from high-density populations into these vacant territories (Minnie *et al.*, 2016a), this may allow the recovery of hunted populations (i.e. compensatory immigration).

The combination of compensatory immigration and reproduction (see Box 7.2) in hunted black-backed jackal populations contributes to the persistence of black-backed jackals in the face of severe persecution, and indicates that lethal control of black-backed jackal populations to reduce livestock losses is unlikely to be successful if recruitment from un-hunted areas persists (Minnie *et al.*, 2016a; 2018). However, this conclusion is based on the results from a single study and spatial replication of this research is required to determine if this pattern persists across habitats. This is likely the case as similar patterns have been documented for several lethally managed canids (e.g. coyote, Knowlton *et al.*, 1999; culpeo fox (*Pseudalopex culpaeus*), Novaro, Funes & Walker, 2005; dingo, Allen 2015; red fox, Lieury *et al.*, 2015).

Caracal

Caracals may disperse from their natal range at between nine months and two years of age (Drouilly *et al.*, unpubl. data; Serieys, L. pers. comm.) and dispersal is likely driven by intraspecific competition with dominant individuals. Sex-biased dispersal has been documented for several felids, with males dispersing over longer distances than females. This increases the likelihood of dispersing males coming into contact with livestock, resulting in male-biased livestock predation (e.g. leopard, Esterhuizen & Norton, 1985; cougar, Ross, Jalkotzy & Gunson, 1996; European lynx, Odden *et al.*, 2002). This may also be the case for caracal. Some studies have reported that caracals can disperse over long distances (> 90 km; Stuart, 1982; Norton & Lawson, 1985; Avenant & Nel, 1998). Additionally, there is a general lack of information on dispersal barriers. High or electrified fences may prevent dispersal, but it is unlikely that fences represent a putative barrier.

Similar to black-backed jackal (see Black-backed jackal dispersal), the lethal management of caracal in livestock farming areas may result in the immigration of individuals from neighbouring areas where they are not managed (e.g. nature reserves). According to Visser (1978), cited in Nowell & Jackson (1996), caracals may recolonize farming areas after extirpation. This compensatory immigration has been documented for other felids (e.g. Iberian lynx, Gaona, Ferreras & Delibes, 1998; mountain lion *Puma concolor*, Robinson

et al., 2014), but no research has been conducted on caracal. Here, we hypothesise that this may be the case. However, there is a severe lack of information on caracal dispersal and the factors that may influence it, and it is one of the least studied aspects of their biology and ecology (du Plessis *et al.*, 2015). This lack of information on dispersal and dispersal barriers hampers our ability to predict the population level responses of caracal to suggested/implemented management actions aimed at reducing predation.

POPULATION DENSITY

Accurate estimates of population density for black-backed jackals and caracals in South Africa are lacking (Avenant *et al.*, 2016; Minnie *et al.*, 2016a), though many farm and reserve managers suggest that black-backed jackal and caracal densities have increased over the last 10-15 years (Avenant & Du Plessis, 2008; Du Plessis, 2013). The population density of black-backed jackals and caracals is likely related to territory size, social structure, the number of non-territorial individuals in the population, and the population growth rate. All these factors vary in accordance with local environmental conditions and resource abundance (Loveridge & Nel, 2008) and may be augmented by anthropogenic habitat modification and predator and prey management. It is of the utmost importance to develop accurate assessment methods to estimate population densities across various land uses for both black-backed jackals and caracals. This will provide the essential baseline information required for successful adaptive management.

Black-backed jackal

Several authors have estimated local population densities via extrapolating home range size, spoor counts and mark-recapture methods. Population density varies with location and recorded densities include: 35 – 40 jackals/100 km² in the Giant's Castle Nature Reserve, uKhahlamba-Drakensberg Park, KwaZulu-Natal Province (Rowe-Rowe, 1982); 50 jackals/100 km² in the Serengeti National Park, Tanzania (Waser, 1980); 54 – 97 jackals/100 km² in Hwange National Park, Zimbabwe (Loveridge & Nel, 2013); 400 – 700 jackals/100 km² in the Tuli Game Reserve, Botswana (McKenzie, 1990). Additionally, extremely high densities (equivalent to 2200 jackals/100

km²) have been recorded at the seal colonies in Namibia – these colonies representing a highly abundant year-round resource (Hiscocks & Perrin, 1988). Although these are crude estimates, it suggests that increased resource availability is correlated with increased population size. There is no information on densities on commercial livestock farms, game farms and communal areas.

Caracal

Caracal density has been estimated for a small number of reserves by extrapolating home range size. Population density in the Mountain Zebra National Park, Eastern Cape Province, was estimated at 38 caracals/100 km² (Moolman, 1986), and in the Postberg Nature Reserve, Western Cape Province, it ranged between 23 – 47 caracals/100 km² (Avenant & Nel, 2002). No other population density estimates exist for the caracal.

CONCLUSION

One might expect that research pertaining to the biology and ecology of black-backed jackals and caracals would be substantial given their role as livestock predators. However, this is not the case. Throughout this chapter we highlighted several data deficiencies and indicated areas where research is urgently required to address predation on livestock and valued wildlife species (summarised in Box 7.3). The available research has been biased towards the feeding ecology of the two species, with comparatively little information on social behaviour, activity patterns, reproduction, home range and habitat selection, dispersal, and population densities. Additionally, research is spatially biased, focusing on a subset of biomes. Given the adaptability of these predators, research needs to be replicated across several habitats to allow for accurate predictions on variation in biology and ecology between regions.

Most research on black-backed jackals and caracals has been conducted in nature reserves, with little research emanating from commercial livestock farms, game farms and communal areas. The anthropogenic impacts (e.g. prey and predator management) vary tremendously between these land uses, which should translate into variation in the biology and ecology of both black-backed jackals and caracals. However, relatively little research comparing biological and ecological variation

between these land uses (particularly communal areas) has been conducted (see du Plessis *et al.*, 2015 for review). Further, research has focused relatively more on black-backed jackals than caracals (Figure 7.1). This is not surprising given the fact that across South Africa, black-backed jackals are the most problematic predators of livestock (Chapter 3).

The collection of baseline information on black-backed jackal and caracal biology and ecology on nature reserves, commercial livestock farms, game farms and communal areas is needed for the development of evidence-based management strategies for these areas. Without it, predator management activities will continue

to be haphazard and ineffective at reducing livestock damage. The demographic, ecological, behavioural and dietary plasticity of black-backed jackals, and to a lesser extent, caracals, are probably the main factors contributing to the persistence of these species across the South African landscape. This flexibility allows them to adjust to the current prey and predator management regimes. Thus, any management aimed at modifying black-backed jackal and caracal population densities should be grounded in a sound knowledge of their biology and ecology. If this is not the case, current management practices will continue with little success.

Box 7.3 Knowledge Gaps

The collection of appropriate baseline biological and ecological data is extremely important. Without this information the responses of predator populations to prey and predator management strategies cannot be assessed. Below we highlight the important knowledge gaps where research is required in order to address predation by black-backed jackal and caracal.

- » How much livestock and valued wildlife species do black-backed jackals and caracals kill, and what are the implications of this for the livestock and game farming industries?
- » Do increased densities of natural prey buffer livestock losses?
- » How does variation in predator management (lethal versus non-lethal) affect the social structure, activity patterns, reproduction, home range, population density, habitat selection and dispersal of these mesopredators?
- » Which tools can accurately predict the density of these mesopredators?
- » What is the population size and trend of the black-backed jackal and the caracal in South Africa?
- » Are there “hotspots” of predation where most of the attacks on livestock and valued wildlife species occur?
- » Is livestock predation a learnt behaviour resulting in a few individuals killing livestock (i.e. problem individuals), as opposed to the entire population?

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CHAPTER 7

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THE ROLE OF MESOPREDATORS IN ECOSYSTEMS: POTENTIAL EFFECTS OF MANAGING THEIR POPULATIONS ON ECOSYSTEM PROCESSES AND BIODIVERSITY

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INTRODUCTION

*Predators have considerable impacts on ecosystems and biodiversity, with many recent studies highlighting their strong top-down effects that influence ecosystem structure and function. The majority of these insights come from studies on a handful of large charismatic predators (i.e. lions *Panthera leo*: referred to as apex predators when these large predators dominate the food chain) (Roemer, Gompper & Valkenburgh, 2009; Ripple et al., 2014). The removal of these apex predators has a disproportionately disruptive influence on ecosystem structure and function (Ripple et al., 2014). However, most predators are neither large nor charismatic and consequently have received relatively little research attention compared with the small group of apex predators upon which much research time and funding are focused (Roemer et al., 2009). These small- to medium-sized predators, collectively called mesopredators (Prugh et al., 2009), are often capable of living close to humans and can attain population densities considerably greater than that of apex predators (DeLong & Vasseur, 2012). Through their combined influence, mesopredators have the capacity to influence ecosystems (Roemer et al., 2009; Williams et al., 2017). Despite this, we know very little about their ecological roles and how fluctuations in their abundance influence biodiversity.*

IN natural ecosystems, where present, large predators can regulate the abundance and, therefore, the impact that mesopredators may have on ecosystems and biodiversity (Crooks & Soulé, 1999; Morris & Letnic, 2017).

In the absence of apex predators, mesopredators alter their foraging behaviour and may increase in abundance through a process known as mesopredator release (Soulé et al., 1988), and are then functionally elevated

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to the position of top predators in ecosystems.

In human dominated landscapes, large tracts of land are used for agriculture and human habitation, with those areas for agriculture placed under varying intensities of livestock and crop production (Osinubi, Hand, Van Oijen, Walther & Barnard, 2016). Furthermore, landscape conversions are often associated with a simplification of the faunal and floral assemblages, typically including the loss of apex predators. Therefore, in the Anthropocene, mesopredators exist under circumstances of multiple land-use types, fulfilling a myriad of ecological roles (Prugh *et al.*, 2009).

In South Africa, a variable and context-dependent trophic status of mesopredators prevails (some ecosystems retain large predators, some ecosystems are largely intact despite the absence of large predators, and some ecosystems are completely altered and simplified for agricultural purposes) (Figure 8.1). In agricultural landscapes, mesopredator persecution by humans might replace the regulatory impacts of extirpated apex predators. However, it is not fully understood how this differs from top-down regulation by apex predators, given the spectrum of control options used to combat problem-causing animals (See Chapter 6).

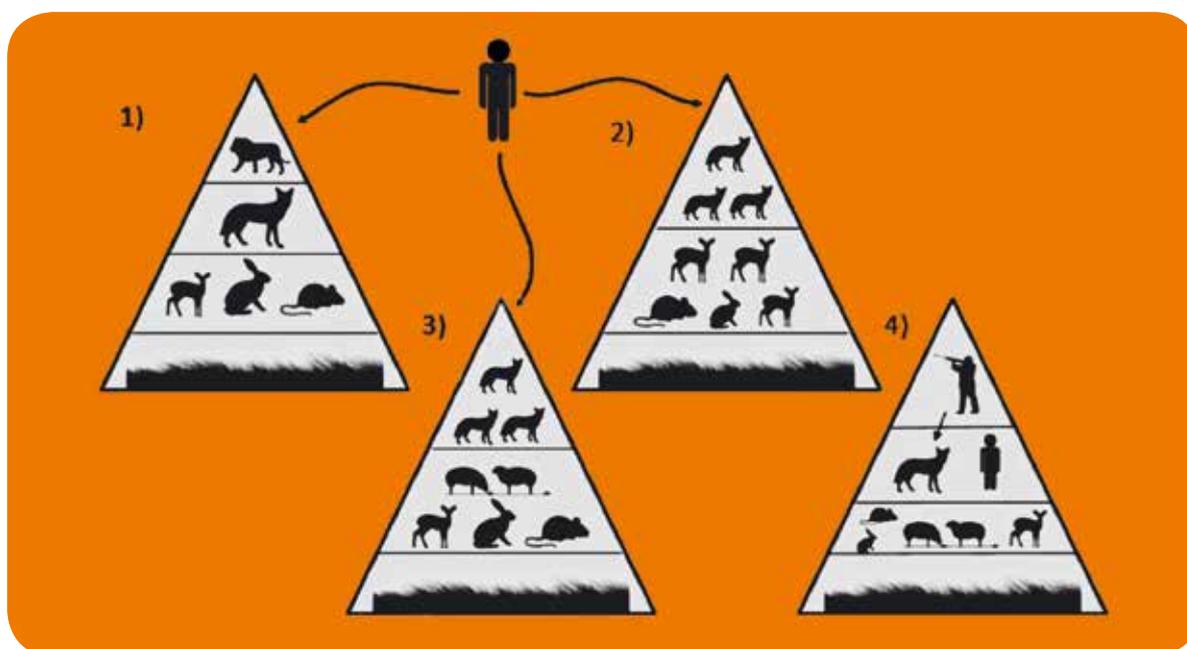


Figure 8.1. Graphical representation of various ecosystems in South Africa; 1) an intact ecosystem where apex predators are present and mesopredators consume a range of wild small ungulates and small mammals, which in turn feed on vegetation, 2) an ecosystem where apex predators have been extirpated and mesopredators are released from top-down control and consume large prey along with small mammals, which in turn feed on vegetation, 3) a modified ecosystem where apex predators have been extirpated and mesopredators are released from top-down control and consume ungulates, small mammals and livestock which in turn feed on vegetation (for ecosystems 1-3: humans, although not present in the food chain, can have considerable impacts on these ecosystems through management, poaching, hunting and conservation initiatives), 4) a highly modified ecosystem where apex predators have been extirpated, mesopredators are persecuted by humans while feeding on a range of ungulates, small mammals and livestock which in turn feed on vegetation (for ecosystem 4: humans consume livestock and thus also compete with mesopredators). For all scenario's, silhouette size has no meaning and only the number of jackal silhouettes reflect mesopredator abundance (greater predator abundance expected where top-down control is lacking). Furthermore, for all scenarios mesopredator diets will also include a range of non-mammalian vertebrate, invertebrate prey and fruit.

Considering the diverse array of land uses and the long history of problem animal persecution in South Africa (See Chapter 2), it would be reasonable to expect that ample research has been conducted on the ecological role of mesopredators across this ecosystem continuum. This is, however, far from the reality, and our current understanding of the role of these predators in various ecosystems in South Africa is poor (du Plessis, Avenant & De Waal 2015). We are only starting to understand mesopredator biology (See Chapters 7 & 9), let alone the complex interactions that mesopredators have with sympatric biota. This fundamental lack of information has hindered management; this is exemplified by the myriad of largely ineffective control measures deployed to reduce the impact by mesopredators on livestock in South Africa (Chapter 6).

Here, we investigate the ecological role of mesopredators in relation to their functional position in the food web (i.e. apex or mid-level predators) and the complexity of the ecosystem (agricultural landscapes or natural ecosystems). In addition, we consider the impact that humans may have by filling the role of apex predators in ecosystems where apex predators have been extirpated. We start by identifying the ecological roles of mesopredators and then try to elucidate the functional roles of black-backed jackal *Canis mesomelas* and caracal *Caracal caracal* in South Africa. However, although basic information exists for these species' diets (See Chapter 7), available scientific information relating to their functional roles in ecosystems is limited. We will therefore draw on available information from the functional roles of related taxa (or ecological surrogates) to infer possible additional ecological roles of mesopredators across southern African ecosystems.

We therefore address the following questions:

- » What are the functional roles of mesopredators (global scale)?
- » What are the functional roles of black-backed jackals and caracal in South African ecosystems?
- » What can we learn from international canid and felid research that may be relevant to understanding black-backed jackal and caracal functional roles in South Africa?
- » What are the predicted / possible biodiversity implications (direct and indirect) of attempting

to remove black-backed jackal and caracal from farmlands in South Africa?

By highlighting these issues, we will further explore what information is needed to understand the functional role that two ubiquitous mesopredators play in South African ecosystems, namely black-backed jackal and caracal.

ROLE OF MESOPREDATORS IN ECOSYSTEMS

Mesopredators generally weigh less than 25 kg (see Carbone, Teacher & Rowcliffe, 2007; Prugh *et al.*, 2009; Ripple *et al.*, 2014; Wallach, Izhaki, Toms, Ripple & Shanas, 2015 for specific weight thresholds) and their populations can be regulated through top-down control by larger predators (i.e. apex predators for many mesopredators, Prugh *et al.*, 2009; Ritchie & Johnson, 2009) as well as through bottom-up processes like food availability (López-Bao, Rodríguez & Palomares, 2010). In habitats devoid of apex predators, human persecution of mesopredators may replace the regulatory role of apex predators. However, due to mesopredators typically having a varied and adaptable diet, their ability to live close to humans, and their capacity for high population growth rates, humans often struggle to regulate their numbers (Dorresteijn *et al.*, 2015). Where top-down control does happen, this often limits the ecological impact that mesopredators have on ecosystems and sympatric biodiversity (Berger & Conner, 2008; Ritchie & Johnson, 2009).

However, where top-down regulation of mesopredators is absent, mesopredator release may occur, with mesopredators increasing in abundance and, ultimately, changing their impacts on the ecosystem (Courchamp, Langlais & Sugihara, 1999; Crooks & Soulé, 1999; Ritchie & Johnson, 2009). Under these conditions, mesopredators become the top predators in ecosystems; however, due to allometric constraints related to prey body size, their impacts may not extend to very large prey species. The resulting elevation of mesopredator to top predator status coincides with top down regulation on a range of species on parallel and lower trophic levels (Myers, Baum, Shepherd, Powers & Peterson, 2007). The discussion below, on the role of

mesopredators in ecosystems, includes their ecological roles in a) intact systems where large apex predators are present and b) systems where apex predators have been lost. We conclude our discussion of mesopredator ecological roles by highlighting the roles that ecological complexity (i.e. predator and prey diversity and species richness) and productivity play in modulating the effects of mesopredator function in ecosystems.

Mesopredators' ecological roles under top-down regulation by apex predators

Mesopredators are important drivers of ecosystem function, structure and dynamics. Due to metabolic scaling (Carbone *et al.*, 2007), mesopredators regulate prey populations that are not regulated by large predators and the latter may also regulate prey populations that mesopredators are unable to regulate. Mesopredators can subsist on a diet of invertebrates, plants and small vertebrate prey, whereas larger predators need to consume large vertebrate prey to meet metabolic requirements (Carbone, Mace, Roberts & MacDonald, 1999). Thus, mesopredators are important predators of small vertebrates (i.e. lagomorphs, birds and rodents), including pest species (Newsome, 1990), and can indirectly shape plant communities through predation on seed predators (Asquith, Wright & Clauss, 1997; DeMattia, Curran & Rathcke, 2004) or by directly dispersing seeds themselves (Silverstein, 2005; Jordano, García, Godoy & García-Castaño, 2007).

Many mesopredators are facultative scavengers that provide valuable ecosystem services in the form of waste removal (Ćirović, Penezić & Krofel, 2016). Mesopredators can be important reservoirs of diseases that may negatively impact humans (e.g. bat-eared fox *Otocyon megalotis* can transmit rabies) (Thomson & Meredith, 1993), domestic and wild ungulates (e.g. Bovine tuberculosis spread by badgers *Meles meles*) (Woodroffe *et al.*, 2006) and sympatric predators (Hennessy *et al.*, 2015). The transmission of pathogens to the relatively smaller populations of apex predators can be ecologically devastating, as large predators may be more vulnerable to stochastic disease outbreaks (Kissui & Packer, 2004). The introduction of canine parvovirus from dogs *Canis familiaris* into the gray wolf *Canis lupus* population on Michigan's Isle Royale

led to a decline in wolf numbers, resulting in a switch from predator regulation to food regulation of the moose *Alces alces* population (Wilmers, Post, Peterson & Vucetich, 2006). However, mesopredators could also indirectly protect human health by reducing population size of rodent reservoirs of human disease (Ostfeld & Holt, 2004). Mesopredators can be important links between ecological communities by directly thwarting or facilitating nutrient subsidies (Roemer *et al.*, 2009). For example, river otters *Lontra canadensis* link aquatic and terrestrial communities through their latrines (depositing aquatically-derived nutrients on terrestrial landscapes) (Ben-David *et al.*, 2005; Crait & Ben-David, 2007).

Mesopredator ecological roles without apex predator regulation

With large terrestrial mammalian carnivores having declined by 95-99% globally (Berger, Swenson & Persson, 2001; Ripple *et al.*, 2014) we are now experiencing important changes in terrestrial trophic dynamics and community organization (Ritchie & Johnson, 2009). Following apex predator removal, mesopredator release may occur. Under these circumstances, along with maintaining their functional role as described above, mesopredators can also assume the ecological role of *de facto* apex predators through direct predation effects and indirect fear-driven effects at multiple trophic levels (Palomares & Caro, 1999; Ripple & Beschta, 2004). Thus, following mesopredator release, there is often an increase in predation pressure and a reduction in biodiversity (Wallach *et al.*, 2015). One of the most studied consequences of mesopredator release is the impact that dominant mesopredators have on subordinate sympatric mesopredators. During mesopredator release, dominant mesopredators increase in abundance if they are not regulated by bottom-up processes (see ecosystem complexity below), often negatively impacting smaller predators. In contrast, when apex predators are re-established, the abundance of the dominant mesopredator often declines, cascading into the increase of smaller predators, with ecosystem shifts taking place (Newsome & Ripple, 2015). For example, on the California Channel Islands, the island fox *Urocyon littoralis* was the top predator and inhibited its only competitor, the island spotted skunk *Spilogale*

gracilis amphiala. However, following the arrival of golden eagles *Aquila chrysaetos*, a superior predator, island fox abundance declined, which precipitated an increase in spotted skunk abundance (Roemer, Donlan & Courchamp, 2002).

Much ecosystem destabilisation is the direct result of anthropogenic disturbance. Considering anthropic impacts on ecosystems, mesopredators' ascension to top predator status is likely to become more common and it is crucial to recognize this when drafting management and conservation plans. It is also important that research be designed, and implemented, to take advantage of the loss or reintroduction of apex predators to increase our understanding of the interacting roles of predators in ecosystems. The difference in the impact of mesopredators when filling the functional role of meso- vs top-level predators is at times quite stark. As mesopredators, feral cats *Felis catus* are predators of small prey species such as rodents, lizards and birds in many continental ecosystems (Crooks & Soulé, 1999; Doherty *et al.*, 2015). However, where cats have been introduced onto islands, they are often the top predator and can cause the decline (cats are the principal threat to almost 8% of all critically endangered birds, mammals and reptiles) and in extreme cases the extinction (14% of global bird, mammal and reptile extinctions) of prey populations (Medina *et al.*, 2011). The ecological impact of cats is most pronounced when they are an invasive species and not regulated by apex predators. Mesopredator release also has the potential to lead to the extinction of certain prey species (Soulé *et al.*, 1988; Palomares, Gaona, Ferreras & Delibes, 1995; Burbidge & Manly, 2002), particularly those with low population growth rates or those that are susceptible to mesopredator predation (Courchamp *et al.*, 1999). For example, on the Virginia barrier islands (USA), the presence of racoon *Procyon lotor* and red fox *Vulpes vulpes* are major obstacles for the recovery and conservation of beach-nesting and colonial waterbirds (Porter, Dueser & Moncrief, 2015).

In many agricultural systems, historic top-down regulation of mesopredators due to apex predators can partially be replaced by persecution by humans. Furthermore, mesopredator prey assemblages are supplemented with domestic animals. Top-down effects by humans seldom replicate the full suite of regulative influences that apex predators exert on mesopredators

(Peckarsky *et al.*, 2008) and prey resource supplementation through livestock husbandry may reduce bottom-up constraints. However, the addition of livestock to the system may also negatively affect wild ungulates (Ripple *et al.*, 2015) and rodents (Eccard, Walther & Milton, 2000) through competition for resources and therefore lower the natural prey availability to mesopredators, possibly increasing bottom-up constraints. Agricultural landscapes are often characterised by simple linear food chains (see ecological complexity below); with either mesopredator hyper-abundance (release) or extermination likely to have pervasive ecological effects (Roemer *et al.*, 2009). Mesopredator release may result in pest problems for both commercial and small-scale small-livestock enterprises. Across South Africa, the extirpation of large predators on farmlands, along with the development of agricultural practices, is thought to have led to increases in black-backed jackal and caracal populations, potentially creating bigger challenges in terms of livestock depredation (Humphries, Hill & Downs, 2015; Kerley *et al.*, 2017).

In urban landscapes where development is intensive and humans do not regulate mesopredators, mesopredators exploit the niche space vacated by apex predators (Prugh *et al.*, 2009). For example, in coastal southern California, most of the native sage-scrub habitat has been transformed leading to the local decline of the most common large predator, the coyote *Canis latrans* (Crooks & Soulé, 1999). Lower coyote abundances and increased anthropogenic food availability have resulted in release of various native mesopredators including the striped skunk *Mephitis mephitis*, racoon, grey fox *Urocyon cinereoargenteus*, domestic cat and Virginia opossum *Didelphis virginiana* (Crooks & Soulé, 1999). The release of these predators from top-down control has led to increased mortality of prey species of these smaller predators.

Ecological productivity and complexity and carnivore diversity modulating ecosystem impacts of mesopredators

In many ecosystems, untangling the relative influence that bottom-up versus top-down effects have on mesopredator abundance is difficult. Bottom-up effects can include both ecosystem productivity (i.e.

resource availability) and complexity (number of links and interactions in food webs). For example, during agricultural expansion in Sweden, apex predators (wolf and Eurasian lynx *Lynx lynx*) numbers declined. Consequently, in productive habitats, red fox population growth rates increased considerably following the relaxation of regulation by apex predators. In contrast, in low productivity habitats, red fox population growth rates showed little change following apex predator extirpation (Elmhagen & Rushton, 2007). Low productivity environments are often characterised by considerable variation in climate and resource abundance, with abiotic factors often playing a larger role in structuring ecosystems than biotic interactions (Roemer *et al.*, 2009). In particular, rodent abundance (an important resource for many mesopredators) in arid and semi-arid regions is more strongly influenced by rainfall variation than predation (Jaksic, Silva, Meserve & Gutiérrez, 1997), limiting the cascading impact that mesopredators could have. Therefore, ecosystem productivity may play a key role in governing the magnitude of the response from mesopredators following the removal of the regulation from apex predators.

Contrasting responses and impacts of mesopredators on ecosystems may reflect the complexity of the habitat that the mesopredator occupies. Mesopredators have larger impacts in simple linear ecosystems than on complex ecosystems (Roemer *et al.*, 2009). For example, in the diverse Atlantic forests, the loss of jaguars *Panthera onca* and pumas *Puma concolor* has resulted in the ocelot *Leopardus pardalis* being elevated to the highest-ranking predator in these forest patches. However, in these forest ecosystems, ocelots do not appear to have significant detrimental impacts on sympatric mesopredators (Massara, Paschoal, Bailey, Doherty & Chiarello, 2016). Similarly, mesopredator release may be less prevalent in ecosystems with many competing mesopredators with overlapping niches such as in South Africa. In contrast, the introduction of cats onto islands that are characterised by simple linear food webs results in strong top-down control of the native mesopredators and prey species with observable knock-on effects for biodiversity (Medina *et al.*, 2011). Thus, the impacts of predator rearrangement in complex systems may have greater time lags for observable ecological changes than relatively simple linear ecosystems with fewer

mesopredator species. Ecosystem productivity and complexity may be important in governing mesopredator responses to reduced regulation of mesopredators in agricultural ecosystems (discussed later). It is likely that ecosystem productivity and complexity (including predator diversity and species richness), will determine the relative strength and direction of interactions among predators through food availability, habitat structure and complexity of food webs. The roles of mesopredators in ecosystems is therefore context-dependent and a result of complex interactions between top-down and bottom-up factors (Monterroso, Rebelo, Alves & Ferreras, 2016).

ROLE OF BLACK-BACKED JACKALS IN ECOSYSTEMS

Understanding the role of black-backed jackals (10.3 kg: mean weight - taken from Wallach *et al.*, 2015) in ecosystems in southern Africa is challenging due to their elusive nature (James, James, Scott & Overall, 2015). Despite the long-standing problem of black-backed jackal predation on livestock, our understanding of their ecology has seldom extended beyond that of cursory single species investigations of diet, activity patterns, and only recently, genetics and reproduction (See Chapter 7). Single species studies hinder our ability to understand the role that black-backed jackals play in ecosystems and their impact on sympatric biodiversity. Faced with the daunting task of unpacking the ecological role of black-backed jackals, starting with the diet (the most well studied component of black-backed jackal biology – see Chapter 7) seems logical.

Black-backed jackals are omnivorous, with diets varying widely in relation to food availability. Across most of their range, black-backed jackals prefer smaller ungulates that hide their young while avoiding both larger ungulates that hide their young and ungulates whose young follow the parents from an early age (Klare, Kamler, Stenkewitz & MacDonald, 2010; Hayward *et al.*, 2017). Hayward and colleagues further suggest that black-backed jackal diets are influenced by both top-down (apex predator presence or absence) and bottom-up (prey size and life history pattern) processes. At high black-backed jackal densities, which can occur under conditions of high resource availability (Oosthuizen

et al., 1997; Jenner, Groombridge & Funk 2011; Yarnell, Phipps, Dell, MacTavish & Scott, 2015) and reduced competition, as is also the case for golden jackal *Canis aureus* (Singh, Mukherjee, Dookia & Kumara, 2016), black-backed jackals exhibiting the above preference strategy may limit populations of small ungulates that employ a hider strategy (Morwe, 2013). Black-backed jackals have been recorded as regulating populations of springbok *Antidorcus marsupialis* in the Northern Cape, South Africa (Klare et al., 2010; Morwe, 2013) and blesbok *Damaliscus pygargus* in the Highveld of South Africa (Du Plessis, 1972). In contrast, in the presence of apex predators, and consequential carrion provisioning, peaks in the availability of juvenile ungulates appear to be less important for foraging black-backed jackals (Van de Ven, Tambling & Kerley, 2013; Gerber, 2014), potentially limiting jackal impacts. Contrasting landscapes and / or time periods with and without apex predators provide conflicting perspectives on whether black-backed jackals adjust their foraging behaviour in the presence or absence of large carrion-providing predators (Brassine & Parker, 2012; Yarnell et al., 2013; Fourie, Tambling, Gaylard & Kerley, 2015; Hayward et al., 2017). Thus, it is unknown whether black-backed jackals will regulate populations of small to medium sized ungulates when additional food sources like carrion or livestock are provided.

On farmlands, black-backed jackals are effective predators of livestock (Kamler, Klare & MacDonald, 2012a; Humphries, Ramesh & Downs, 2016), taking advantage of the reduced anti-predator behavioural responses in domesticated species (Mabille et al., 2016). Sheep *Ovis aries* and goats *Capra hircus* can comprise up to 48% of black-backed jackal diets and their consumption tends to peak during the lambing season (Kamler et al., 2012a; Pohl, 2015; Drouilly, Natrass & O’Riain, 2018) and may be dependent on the farming practice employed (Humphries et al., 2015). Thus, the pattern of consumption of livestock by black-backed jackal seems to mimic the patterns exhibited when black-backed jackals consume ungulates in the absence of apex predators. However, despite their consumption of livestock, it remains unclear whether jackals select wild prey more than domestic prey (Northern Cape - Kamler et al., 2012a; Southern Free State - Pohl, 2015) or domestic prey more than wild prey (Central Karoo - Drouilly et al., 2018). The relative

consumption of wild versus domestic prey may however also be dependent on the composition and catchability of wild prey available to black-backed jackal.

Although black-backed jackals hunt and consume small rodents (Hayward et al., 2017), there is no evidence that such consumption provides viable long term pest control services where rodents are crop pests (Swanepoel et al., 2017). However, whereas many rodent species have eruptive life-history characteristics, some, like mole rats (e.g. African mole-rat *Cryptomys hottentotus*), may have lower reproductive potential (Skinner & Chimimba, 2005) and therefore be more susceptible to top-down regulation. The difference in regulatory ability of black-backed jackals to rodents with slow versus fast life-history characteristics has, however, received no attention. Predators of rodents can be distinguished as either specialists or generalists. Generalist predators have access to and use a variety of prey. This habit characterises black-backed jackals and other larger mesopredators discussed in this chapter. Generalist predators tend to stabilise rodent prey populations, although much of the available literature on these dynamics comes from northern temperate regions (Andersson & Erlinge, 1977). In contrast, specialist rodent predators like African wild cat *Felis silvestris lybica* (Palmer & Fairall, 1988), which are often regulated by black-backed jackals (Kamler, Stenkewitz, Klare, Jacobsen & MacDonald, 2012b) are likely to destabilize rodent populations (Andersson & Erlinge, 1977). Since much of the available information on predator-rodent interactions comes from northern temperate regions, it remains to be seen whether black-backed jackals stabilise or destabilise impacts on rodent populations or whether bottom-up processes are more important than predation in South Africa.

In many ecosystems in South Africa, black-backed jackals are now the dominant predator, especially in landscapes where apex predators have been extirpated (Klare et al., 2010). When cast in this role, black-backed jackals seem to suppress populations of smaller and less competitive mesopredators including bat-eared fox, Cape fox *Vulpes chama*, many mongoose species (Kamler et al., 2012b; Bagniewska & Kamler, 2014), black-footed cat *Felis nigripes* (Kamler et al., 2015) and large spotted genet *Genetta tigrina* (Ramesh & Downs, 2014). On farms in the Kalahari where persecution of black-backed jackal is relatively high, the relative

abundances of sympatric mesopredators including bat-eared fox, Cape fox and small spotted-genet *Genetta genetta* are higher than in areas where there are lower levels of human management of black-backed jackals (Blaum, Tietjen & Rossmanith, 2009). Along with direct mortality, black-backed jackals may influence bat-eared foxes in non-lethal ways. Recent evidence suggests that bat-eared foxes form larger groups (Kamler, Rostro-García & MacDonald, 2017) and are more vigilant at night (Welch, Périquet, Petelle & Le Roux, 2017) when living in sympatry with black-backed jackals. These behavioural changes may alter the foraging behaviour of these smaller mesopredators. The direct link between black-backed jackal activity and the observed response from bat-eared foxes is not yet clear, but this research may begin to illuminate some of the non-lethal impacts that black-backed jackals might have on smaller carnivores. These observations were made in the absence of large predators, and whether black-backed jackals have the same impacts (lethal and non-lethal) when they occur in sympatry with large apex predators is unknown.

Black-backed jackals are facultative scavengers and undoubtedly play a role in carrion removal (otherwise known as waste removal as mentioned earlier) on the landscape. In African landscapes, black-backed jackals compete with potentially dominant scavengers (i.e. spotted hyaena *Crocuta crocuta* (Hunter, Durant & Caro, 2007) and brown hyaena *Hyaena brunnea* (Ramnanan, Thorn, Tambling & Somers, 2016)) and where they occur sympatrically with larger scavengers, black-backed jackals may be more reliant on other food sources (Ramnanan *et al.*, 2016). Therefore, although they play important roles in waste removal, they may not be as important as golden jackals have been observed to be in Europe (see below). Both black-backed jackals and side-striped jackals *Canis adustus* are possible reservoirs for rabies (Butler, du Toit & Bingham, 2004), with populations at high densities capable of sustaining disease outbreaks (Cumming, 1982). These disease outbreaks can have societal (spread of rabies to domestic and communal land dogs - Butler *et al.*, 2004) and conservation (spread of rabies to apex predator populations; i.e. African wild dog *Lycaon pictus* – Hofmeyr, Hofmeyr, Nel & Bingham *et al.*, 2004) implications.

The limited scientific understanding of the larger ecological effects of black-backed jackals has recently

come under the spotlight, with a review published in 2015 suggesting that published knowledge on black-backed jackals is limited in scope, geographic location and in most cases outdated (appearing before 2005; du Plessis *et al.*, 2015). Moreover, most of the studies that have been conducted were in protected areas, limiting the application of the findings to unprotected areas. Most of the questions raised by the review by du Plessis and colleagues, however, focused on the biology of black-backed jackals and caracals and these deficiencies are addressed in Chapter 7. As for many other mesopredators, the role that black-backed jackals play in the ecosystem is context-dependent (Fourie *et al.*, 2015), based on the interaction of top-down and bottom-up forces that drive the relative availability of resources. Armed with a catholic diet and a plastic behavioural repertoire, black-backed jackals have the ability to modify their diet, limiting our ability to predict the functional response of black-backed jackals to landscape-level changes or manipulations.

LESSONS FROM CANIDS IN DIFFERENT SYSTEMS

Across the globe, a number of canids occupy similar niches to black-backed jackals. In particular, we will focus on four key species, the golden jackal (11 kg), coyote (13.3 kg), dingo (16.5 kg) and red fox (4.1 kg; weights represent average weights taken from Wallach *et al.*, 2015). It is likely that these species have similar ecological roles to black-backed jackals and we can infer potential black-backed jackal ecosystem roles from these species.

Canid mesopredators, in particular golden jackals and red foxes, play an important role in the regulation of small prey species such as lagomorphs and rodents (Lanszki, Heltai & Szabó, 2006; Dell'Arte, Laaksonen, Norrdahl & Korpimäki, 2007). In Europe, golden jackals are estimated to consume 158 million crop pests a year (Ćirović *et al.*, 2016); undoubtedly limiting the damage these species have in agricultural ecosystems. In Australia, red fox expansion has coincided with declines in populations of small- and medium-sized mammals (Saunders, Gentle & Dickman, 2010; Woinarski, Burbidge & Harrison, 2015) indicating that not only do these mesopredators regulate small prey, but, under certain conditions (i.e. simplified ecosystems with low productivity and few competing

carnivores), reduce prey populations. However, prey population declines in Australia may be the result of different evolutionary paths for those predators and prey. Australian prey did not evolve alongside red foxes (or domestic cats); therefore, where predator and prey have evolved together, as is the case with black-backed jackal and their prey, the impacts of predation may not be as severe. Many of these small- and medium-sized prey species in Australia are important seed predators and increased predation by red foxes have had observable impacts on the composition of the vegetation (Gordon *et al.*, 2017 - see below). In North America, coyotes are similarly important predators of lagomorphs. In many farming areas, the persecution of coyotes has resulted in an increase in the competition between lagomorphs and cattle; with the impacts of lagomorph competition exceeding the impact that predation by coyotes would have on cattle populations (Ranglack, Durham & Du Toit, 2015). Although black-backed jackals consume many similar small prey species, the extent of their population regulatory ability remains largely unknown.

Birds may form an important part of red fox, golden jackal and coyote diets across much of their range particularly during the nesting season when ground-nesting birds may be susceptible to nest and chick predation. Coyote predation on birds at certain times of the year may play an important regulatory role in bird populations (Ripple, Wirsing, Wilmers & Letnic, 2013). Such predation and regulation has both positive and negative impacts, primarily related to human interests. Coyote impact on game bird populations is viewed negatively when hunting bags are reduced with low bird populations (Ripple *et al.*, 2013) or coyotes consume birds of conservation value (Cooper, Jhala, Rollins & Feagin, 2015; Dinkins, Conover, Kirolo, Beck & Frey, 2016). In contrast, coyote regulation of seed eating birds in agricultural landscapes benefits crop farmers (Gabrey, Vohs & Jackson, 1993). Predation on birds by black-backed jackals is predominantly opportunistic and it is unlikely that this predation will have population regulatory effects for birds. However, the presence of black-backed jackals in areas where endangered ground-nesting birds live could have conservation repercussions.

Dingoes and coyotes are important predators of larger prey species (Davis *et al.*, 2015; Benson, Loveless, Rutledge & Patterson, 2017). In the case of the coyote,

their regulatory impact on larger prey species becomes more apparent following the relaxation of regulation by apex predators (Berger & Conner, 2008). Following apex predator extirpation, coyote abundance often increases and predation pressure on the juveniles of some larger prey species (i.e. pronghorn *Antilocapra americana* and Dall sheep *Ovis dalli*) increases (Berger & Conner, 2008; Prugh & Arthur, 2015). In Australia, dingoes regulate and limit populations of larger prey such as red kangaroos *Macropus rufus* and emus *Dromaius novaehollandiae* (Pople, Grigg, Cairns, Beard & Alexander, 2000). It is likely that in the absence of top-down extrinsic regulation, black-backed jackal impacts mirror those of the other medium-sized canids, although the hunting strategy of black-backed jackals (preference for hider species) may lower the relative impacts in comparison to dingo and coyote that may not be limited to hider species. All four canid species are important livestock predators. Not only do dingoes have a direct effect on livestock through predation, but down-stream impacts include reduced grazing of livestock where dingoes are abundant, which has financial implications for agricultural activities (Letnic, Ritchie & Dickman, 2012). Furthermore, the commercial cropping of kangaroos is not viable in areas where dingoes occur (Letnic *et al.*, 2012). Black-backed jackals similarly play an important role in livestock predation (Kamler *et al.*, 2012a; Humphries *et al.*, 2016). At high jackal densities, even limited predation may have significant consequences for livestock farmers.

In the position of top-level predators, medium-sized canids can suppress smaller predators and modulate their impacts on local biodiversity. Dingoes and coyotes in particular have considerable impacts on sympatric mesopredators. Dingoes suppress red fox and feral cat populations via direct killing, competition for resources, and through fear (Letnic *et al.*, 2012). The consequences are that the presence of dingoes buffers smaller prey species from predation by mesopredators (Letnic *et al.*, 2012; Ritchie *et al.*, 2012). Lethal control of coyotes is suggested to increase raven *Corvus corax* nest predation on ground-dwelling birds (Dinkins *et al.*, 2016) and mesopredator rearrangement following coyote extirpation can have severe impacts on lower trophic levels (Crooks & Soulé, 1999; Henke & Bryant, 1999). Red foxes, although being suppressed by dingoes in Australia where the red fox is an introduced species

(Letnic *et al.*, 2011), do exert their own impacts on the smaller Fennoscandian pine marten *Martes martes* (Lindström, Brainerd, Helldin & Overskaug, 1995), as well as the introduced American mink *Neovison vison* and thus dampen the impacts of these smaller predators on small mammals and birds (Carlsson, Jeschke, Holmqvist & Kindberg, 2010). Thus, black-backed jackal impacts on smaller mesopredators are likely to be similar to those of other canid species, with similar cascading or modulating effects through the ecosystem likely to occur.

The top-down effects of medium-sized canids have further cascading impacts on ecosystems. The presence of dingoes permeates to an impact on vegetation - grazing by kangaroos was higher, and grass cover was lower, where dingoes were absent (Wallach, Johnson, Ritchie & O'Neill, 2010). Across Australia, the presence and absence of dingoes and red foxes have cascading impacts on seed predators (i.e. rodents) and therefore shrub cover (Gordon *et al.*, 2017). This knock-on impact has not been investigated for black-backed jackals and it remains to be seen whether their top-down predatory effects are strong enough to generate landscape scale trophic cascades.

Coyotes, golden jackals and red foxes all consume fruits when seasonally available (Dell'Arte *et al.*, 2007; Melville, Conway, Morrison, Comer & Hardin, 2015), thus they all play a role in seed dispersal. It is, however, unknown to what extent black-backed jackals aid seed dispersal. Canid mesopredators will readily consume carrion, undoubtedly providing a key ecosystem service by removing animal waste from ecosystems. Recent estimates suggest that golden jackals can remove up to 13000 t of animal waste across Europe, amounting to an estimated value of €2 million per year (Ćirović *et al.*, 2016). Similarly, red foxes scavenge and readily accept human-derived food (Leckie, Thirgood, May & Redpath, 1998; Contesse, Hegglin, Gloor, Bontadina & Deplazes, 2004). Medium-sized canids may also influence the spread of diseases through complex interactions with their prey and sympatric mesopredators (Levi, Kilpatrick, Mangel & Wilmers, 2012). The relative impact of black-backed jackals as waste removal agents may be dependent on the presence and density of larger obligate scavengers that limit black-backed jackal access to carrion.

Medium sized canids have considerable conservation related roles. Coyotes hybridise with both domestic

canids and canids of conservation concern (Lehman *et al.*, 1991). This hybridisation has been particularly problematic in conservation efforts aimed at restoring red wolf *Canis lupus rufus* populations (Adams, Kelly & Waits, 2003). In addition, domestic dogs have introgressed with other canids including coyotes, wolves and dingoes (von Holdt, Kays, Pollinger & Wayne, 2016). Recently, hybridisation between golden jackal and domestic dogs has been recorded (Galov *et al.*, 2015). Thus, although limited evidence exists of hybridisation between black-backed jackal and domestic dogs, this eventuality cannot be ruled out. Finally, since many medium sized canids have varied diets and exhibit plastic selection patterns based on prey availability, they may hamper the restoration efforts directed at rare and endangered species (Matchett, Breck & Callon, 2013). Since black-backed jackals have similarly varied diets and an opportunistic foraging strategy, they might limit the recovery of threatened species.

ROLE OF CARACAL IN ECOSYSTEMS

Relatively little has been published on the ecology of caracal (16 kg: average weight - taken from Wallach *et al.*, 2015), with virtually no studies of their ecological importance (Du Plessis, 2013). Through their interactions with other predators and / or with prey, however, they most likely play an important role across the spectrum of ecosystem types in which they occur (Du Plessis, 2013). From a biodiversity perspective, caracals potentially influence the structure of communities, regulate prey populations, and maintain biodiversity via the suppression of competing predators and prey populations, although much of this still remains to be investigated.

The presence of caracals on the landscape influences the ecology and abundance of sympatric carnivores. Caracal abundance fluctuates inversely with black-backed jackal where these species occur together (Pringle & Pringle, 1979; Ferreira, 1988). However, since black-backed jackals have a negative impact on smaller mesopredators, this inverse relationship may suggest that caracal presence may result in a positive effect on the abundance of smaller carnivores. However, track counts in the Kalahari show that when caracal and black-backed jackal numbers are reduced, through predator control measures, the abundance of smaller mesopredators increases (Blaum *et al.*, 2009). Furthermore, caracals

regularly prey on smaller predators (see Chapter 7, Palmer & Fairall, 1988; Melville, Bothma & Mills, 2004) suggesting broad scale impacts on the abundance of sympatric mesopredators. Caracals also share a prey base with many co-occurring small carnivores (Bothma, Nel & MacDonald, 1984; Avenant & Nel, 1997; Kok & Nel, 2004; Pohl, 2015), thus increasing interspecific competition for available resources and the likelihood of competitive exclusion.

Few studies have been conducted on the relationship between caracal and their prey (only Moolman, 1986 and Avenant & Nel, 2002). In farming areas, caracal are considered important predators for controlling populations of small mammals (Pringle & Pringle, 1979). These early observations along with numerous diet estimates provide evidence of the potential impact that caracals have on prey species. Caracals regularly consume small mammals weighing up to 10 kg, including rock hyrax *Procavia capensis*, springhares *Pedetes capensis* and smaller rodents (mice, gerbils and molerats) (Avenant & Nel, 1997; Avenant & Nel, 2002; Melville et al., 2004; Braczkowski et al., 2012; Pohl, 2015; Drouilly et al., 2018) and could play a role in ensuring healthy prey populations and a high diversity of small mammal and bird species. Many caracal prey species consume large amounts of plant material and are known to damage natural vegetation and crops, especially where these species occur at high densities (Korn & Korn, 1989; Swanepoel et al., 2017). Estimations from the Karoo National Park suggest that caracals have a major impact on rock hyrax populations, removing as much as 30% of the annual recruitment (Palmer & Fairall, 1988). By killing small prey species it is possible that caracals indirectly impact plant communities and may thus be important ecosystem engineers (Ramesh, Kalle & Downs, 2016), but this needs further investigation.

Caracal kill both adult and juvenile ungulates (Avenant & Nel, 2002; Pohl, 2015). However, whether this predation plays a regulating role on these prey populations is unknown. Caracal are also important predators of livestock, with livestock accounting for as much as a quarter of caracal diets on farmlands in the central Karoo (Drouilly et al., 2018). Furthermore, domestic goats avoid caracal cues, indicating that caracal presence on the landscape creates a landscape of fear (Shrader, Brown, Kerley & Kotler, 2008). It remains to be seen what population level impact this landscape of fear creates (including the interaction between caracal

and valuable game species) and whether the same population level responses, as observed in northern temperate regions (i.e. reduced reproduction, Creel & Christianson, 2008), emerge. Although caracals seldom scavenge, instances of caracals scavenging have been reported (Avenant, 1993; Avenant & Nel, 2002; Drouilly et al., 2018) and consequently they may be responsible for waste removal from ecosystems, however, not to the same effect as habitual scavengers such as the black-backed jackal.

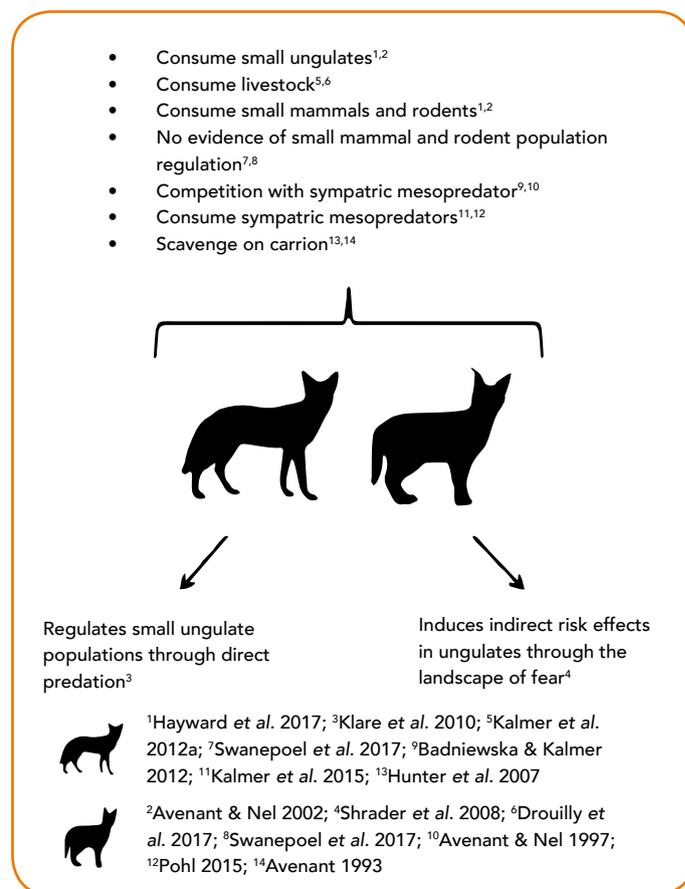


Figure 8.2. Summary of the ecological roles of black-backed jackal and caracal in South Africa based on published information (not all publications included).

LESSONS FROM FELIDS IN DIFFERENT SYSTEMS

Much like black-backed jackals, our understanding of caracals' roles across ecosystems is limited. We therefore investigated other similarly-sized felids from across the globe to infer possible additional ecosystem roles for caracals. In particular, we focused on lynx (Eurasian – 23 kg, Iberian – 11 kg and Canada – 10.1 kg) and bobcats (8.6 kg; weights represent average weights taken from Wallach *et al.*, 2015).

The Eurasian lynx, the largest of the four species, was the only felid investigated that regulated ungulate prey (roe deer *Capreolus capreolus*) (Jedrzejska, Jedrzejski, Bunevich, Milkowski & Krasinski, 1997; Davis, Stephens & Kjellander, 2016). Furthermore, the presence and hunting strategy of lynx influenced the habitat use (Lone *et al.*, 2017), vigilance levels (Eccard, Meißner & Heurich, 2017) and visitation rates to feeding sites (Wikenros, Kuijper, Behnke & Schmidt, 2015) of roe deer. For medium to large cervids (red deer *Cervus elephus* [120-240 kg], woodland caribou *Rangifer tarandus* [113-318 kg] and white tailed deer *Odocoileus virginianus* [45-68 kg]), juveniles are the predominant age-class killed by these felids, whereas, Eurasian lynx kill predominantly adults of the smaller roe deer [10-35 kg] (Mejlgaard, Loe, Odden, Linnell & Nilsen, 2013; Williams & Gregonis, 2015; Heurich *et al.*, 2016; Mahoney *et al.*, 2016). However, in the case of both the Eurasian and Canada lynx *Lynx canadensis*, yearlings and sub-adult lynx show greater flexibility in their diets, often selecting prey not utilised by adult lynx to avoid competition with adults for preferred prey (Mejlgaard *et al.*, 2013; Burstahler, Roth, Gau & Murray, 2016). Although ungulates are consumed by caracals, we do not know whether this predation has the same regulating role as observed for Eurasian lynx and their main ungulate prey.

Like caracals, all four felid species include small mammals in their diet, with the three smaller species preying predominantly on small mammals. Canada lynx and Iberian lynx *Lynx pardinus* prey heavily on lagomorphs, and in the case of Canada lynx their association with snowshoe hares *Lepus americanus* may drive the observed 9-10 year so-called lynx-snowshoe hare cycles (Krebs *et al.*, 2014). Importantly, Iberian lynx are reliant

on European wild rabbits *Oryctolagus cuniculus*, and declines in this food source are postulated as a key driver for the precipitous decline of Iberian lynx (López-Bao *et al.*, 2010). However, despite the importance of European wild rabbits in their diet, the presence of lynx has a positive effect on rabbit abundance by regulating populations of Egyptian mongoose *Herpestes ichneumon* (Palomares *et al.*, 1995 - see below), a specialist rabbit predator. Caracals similarly consume small mammals, however it is not known if this predation is regulative or whether abiotic factors may be more important for the regulation of small mammal prey. Understanding the top-down and bottom-up processes governing prey species will provide a better understanding of the possible cascading roles that caracal extirpation or hyper-abundance may provide.

The four felid species, like caracals, have important interactions with their respective sympatric carnivores. This impact, however, varies between species and is greatest for the largest species, Eurasian lynx, which is typically described as an apex predator. The Eurasian lynx is an important predator, providing carrion for scavengers like wolverine *Gulo gulo* (Khalil, Pasanen-Mortensen & Elmhagen, 2014; Mattisson *et al.*, 2014) and red foxes (Helldin & Danielsson, 2007). Despite providing food for red foxes, Eurasian lynx have a direct negative impact on red fox abundance (Pasanen-Mortensen, Pyykönen & Elmhagen, 2013) through intra-guild predation which is additive to other forms of natural mortality (Helldin, Liberg & Gloersen, 2006). Both Iberian lynx and bobcats influence red fox activity patterns (Penteriani *et al.*, 2013; Lesmeister, Nielsen, Schaubert & Hellgren, 2015). Bobcats, however, occur sympatrically with numerous smaller mesopredators whose space use is influenced more by habitat variables than bobcat presence (Lesmeister *et al.*, 2015). Furthermore, some smaller omnivores like opossums obtain seasonal food supplementation from bobcat scats through coprophagy (Livingston, Gipson, Ballard, Sanchez & Krausman, 2005). Although we know that caracals may have negative impacts on smaller mesopredators, we do not fully understand the mechanisms of these interactions.

Interactions of these four felid species on agricultural landscapes are complex and often context-dependent. Canada lynx are seldom implicated in livestock predation (Mumma, Soulliere, Mahoney & Waits, 2014)

and Iberian lynx have only recently started to impact livestock (predominantly poultry but some sheep) as their abundance increases (Garrote *et al.*, 2013). Most of our understanding of lynx-livestock interactions comes from Eurasian lynx in Europe. Livestock predation in multi-use landscapes is varied, with contrasting findings from various studies. In some regions predation on sheep is lower in areas with high roe deer densities (Odden, Nilsen & Linnell, 2013), whereas in other regions livestock predation was higher in areas with high roe deer densities (Stahl *et al.*, 2002). Predation on sheep peaked in summer (Gervasi, Nilsen, Odden, Bouyer & Linnell, 2014), when roe deer are not thermally or nutritionally stressed (Lone *et al.*, 2017). Where sheep densities are low, female lynx seldom kill sheep irrespective of roe deer density whereas predation on sheep by males was generally higher at high roe deer densities (Odden *et al.*, 2013). Furthermore, female lynx with new-born young often avoid human activity, even if high levels of prey are available near human settlements (Bunnefeld, Linnell, Odden, van Duijn & Andersen, 2006). In general, lynx were more likely to kill sheep when pastures were close to intact forest fragments, far from human settlements, associated with a high availability of roe deer and near to a pasture where livestock were previously attacked (Stahl *et al.*, 2002). Lynx predation can be explained by a predictable set of habitat features that expose sheep on certain pastures to increased risk (Stahl *et al.*, 2002). Developing an understanding of the interaction between local wild prey and livestock may assist in understanding the relative impact that caracals could have on livestock and wild prey populations.

BIODIVERSITY IMPLICATIONS OF MESOPREDATOR REMOVAL

It is clear that mesopredators are vital for ecosystem functioning and biodiversity. The global trend that the majority of research effort and funding is directed at charismatic apex predators holds true for South Africa. Furthermore, not only is the bulk of scientific inquiry aimed at this small subset of large predators (albeit those with a large ecological impact), but the majority of the research is also focused in a few select ecosystems. Moreover, until recent technological advancement in research tools, research on mesopredators was hindered by logistical constraints. This chapter has highlighted the

multitude of ecological roles that mesopredators play; however, our general understanding of these roles for black-backed jackals and caracals is limited.

Both black-backed jackals and caracals are important predators of small mammals; however, understanding the regulatory or population level impacts of predation by these mesopredators remains limited. Furthermore, jackals are important predators and regulators of small- to medium-sized ungulates through the selective predation of neonates that hide. Targeted predation on neonates that hide could play an important role in population regulation of high value game species like roan *Hippotragus equinus* and sable *Hippotragus niger* antelope. Such predation might result in increased retaliatory killing by farmers due to the perceived reduction in revenue (Pirie, Thomas & Fellowes, 2017). In contrast, the regulatory role of caracals on ungulate populations remains poorly investigated. The predatory impact of these mesopredators varies depending on prey size and life history characteristics. Unfortunately, we need a better understanding of how these mesopredators regulate prey from the prey's perspective, rather than through more diet estimates and this should be a priority for understanding the repercussions of mesopredator management. Furthermore, the relative roles of apex predators (and their identity) on the regulatory ability of these species requires further investigation.

Through understanding important prey population responses to predation by black-backed jackals and caracals we will also increase our understanding of whether or not the presence of these mesopredators influences vegetation at a landscape scale. However, South Africa is characterised as semi-arid to arid with fairly low productivity. Research suggests that under this scenario of low productivity, biodiversity is more likely to be controlled by bottom-up than top-down mechanisms. However, both mesopredator species also occur in the more productive eastern regions of South Africa (savannah and grassland biomes), and it is in these habitats that few studies have been conducted. Therefore, unravelling the main nutrient flows (i.e. contrasting bottom-up and top-down factors) across ecosystem gradients (of which basic data in many of these ecosystems, especially non-protected landscapes, remains lacking) will provide a good basis on which to formulate an estimate of the potential impacts of black-backed jackal and caracal

extirpation or hyper-abundance. However, in contrast to the productivity theory, the extirpation or hyper-abundance of mesopredators from relatively simple agricultural ecosystems could have profound ecosystem impacts that may be dampened in more complex habitats with less linear food webs.

Importantly, both black-backed jackals and caracals mirror observations on other medium sized mesopredators in that they have strong top down effects on smaller mesopredators. In many ecosystems, these regulative effects have knock-on consequences for lower trophic levels and ecosystem structure. This possible ripple effect on ecosystems in South Africa through the presence or absence of these mesopredators has not been studied.

Much of what we know about the removal of these mesopredators from agri-pastoral landscapes comes from inference rather than rigorous inquiry. However, based on the above discussion, removing black-backed jackals and caracals from simple agri-pastoral environments could result in a greater abundance of small mammals (i.e. rodents) that could limit plant regeneration through seed predation (but c.f. Kerley (1992) for evidence of low levels of granivory in Karoo rodents). The loss of

black-backed jackals could result in small ungulate numbers increasing with a resulting increase in livestock-wild ungulate competition. However, under this scenario, the remaining black-backed jackals and caracals would have abundant prey, potentially reducing predation on livestock where wild prey are still preferentially caught (but see ideas about compensatory reproduction in Chapter 7). The loss of black-backed jackals and caracals may result in an increase in population densities of bat-eared fox, Cape fox, black-footed cat, African wild cat, genet species and many mongoose species, but may also lead to differences in their relative abundances (and subsequent losses of prey species of these specialized predators) in certain habitats. These populations may flourish if rodent numbers are high. In other ecosystems, smaller mesopredators have profound impacts on biodiversity and the same might be expected in South Africa. Unfortunately, our understanding of the roles of smaller mesopredators is lacking even more so than for black-backed jackal and caracal, and the resulting predator re-arrangement (abundance and composition) could alter entire small mammal assemblages, resulting in ecosystem scale consequences similar to those observed in simple island ecosystems.

Box 8.1: Knowledge gaps and associated questions for increasing our understanding of the role of black-backed jackal and caracal in ecosystems in South Africa

- » How does the presence or absence of apex predators (including jackal and caracal when filling the role of top predators) influence black-backed jackal and caracal density (and are these influences density dependent)?
- » Do black-backed jackals and caracals regulate the populations of small ungulates (i.e. steenbok) and / or rodents (rats and mice) and / or lagomorphs (rabbits and hares) and /or hyraxes; or alternatively, are these prey populations regulated through bottom-up forces?
- » If caracal and black-backed jackal prey populations increase rapidly, do these species then have negative (direct and / or indirect) impacts on biodiversity (all wildlife) – especially if sheep are protected?
- » In farming areas, do black-backed jackal and caracal distinguish between natural and domestic prey and how does the abundance of “natural” and “domestic” prey influence prey selection of these mesopredators?
- » Are there landscape scale trophic cascades resulting from the localised removal of mesopredators, as seen in Australia?

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BIOLOGY, ECOLOGY AND INTERACTION OF OTHER PREDATORS WITH LIVESTOCK

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INTRODUCTION

*In South Africa, two of the smaller carnivores – caracals *Caracal caracal* and black-backed jackals *Canis mesomelas* – are reportedly responsible for most predation on small livestock (van Niekerk, 2010; Badenhorst, 2014; Kerley et al. 2017). However, other species are also implicated in livestock predation in the country including lions *Panthera leo*, leopards *Panthera pardus*, cheetahs *Acinonyx jubatus*, servals *Leptailurus serval*, African wild dogs *Lycaon pictus*, side-striped jackals *Canis adustus*, Cape foxes *Vulpes chama*, free-roaming dogs (feral or controlled) *Canis lupus familiaris*, spotted hyenas *Crocuta crocuta*, brown hyenas *Parahyaena brunnea*, honey badgers *Mellivora capensis*, bushpigs *Potamochoerus larvatus*, chacma baboons *Papio ursinus*, Nile crocodiles *Crocodylus niloticus*, and various corvids and raptors (e.g. Badenhorst, 2014). While it is well known that large carnivores are important in the top-down regulation of food webs, small carnivores can also, especially in the absence of the large carnivores, play a pivotal role in ecological processes (See Do Linh San & Somers, 2013; Chapter 8). Predators can affect*

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the density and dynamics of prey species, with cascading effects on whole ecosystems (Beschta & Ripple, 2006; Ripple & Beschta, 2007; Wallach, Johnson, Richie & O'Neill, 2010). Large predators, for example, African wild dogs, are also important tourist attractions (Lindsey, Alexander, du Toit & Mills, 2005a). The removal of large predators from an ecosystem may have many unexpected consequences, which from an ecosystem services perspective, can often be negative. In South Africa, many top-order predators have been historically extirpated from much of the land (Boshoff, Landman & Kerley, 2016), with some species (e.g. lions) now surviving mostly in formally protected areas. Some other species such as cheetahs, spotted hyenas, and African wild dogs, although still occurring outside protected areas, are probably dependent on them for continued survival (Mills & Hofer, 1998).

AN estimated 69% (839,281 km²) of South African land is used for domestic livestock farming and game ranching (Thorn, Green, Scott & Marnewick, 2013). The resulting habitat fragmentation caused by this extensive farming restricts the movement of animals with large home ranges, including many predators and their prey (Woodroffe & Ginsberg, 1998), which brings them into conflict with people and their livestock (Thirgood, Woodroffe & Rabinowitz, 2005). In addition, the increasing human density along South Africa's reserve borders is escalating the conflict. There have been numerous reintroduction attempts of especially large predators (some successful, some not) around the world, including South Africa (Hayward & Somers, 2009). Many of these have taken place in small protected areas with substantial edge effects and with a high chance of escape (Hayward & Somers, 2009). In those areas where there has been a historical eradication of predators, there is little culture of shepherding livestock. Conflict is therefore unlikely to decrease and needs to be identified and mitigated against.

Many predators in South Africa exist outside protected areas, and modifications to their habitat by agriculture and other human activities can increase the frequency and intensity of carnivore conflict situations (Thorn, Green, Dalerum, Bateman & Scott, 2012). Humans are now the primary cause of predator mortality (Lindsey, du Toit & Mills, 2005b; Hemson, MacLennan, Mill, Johnson & Macdonald, 2009). This is often because predators may compromise the health and livelihoods of humans living near carnivores (Gusset, Swarmer, Mponwane, Keletile & McNutt, 2009; Dickman, 2010). Livestock production in Africa varies from large scale operations to small scale subsistence livestock farming, typical of most of rural Africa, and many of these people face formidable economic pressures (Hemson,

2003). With the presence of livestock, the dynamics of natural predator-prey systems may change. Predators may alter their activity and movement patterns based on the presence of abundant, easy-to-catch prey (e.g. Somers & Nel, 2004). Much of the discussion below thus needs to be seen in the light that predation is context dependent.

Here we briefly assess aspects of the biology and ecology of predators and how these affect livestock predation. We then review the evidence of their involvement in predation, and we identify which livestock are attacked, categorise the evidence of the predators attacking livestock, and broadly categorise the severity of this predation from injury to death. The ecology and behaviour of the main livestock predators are reviewed to determine how these affect the interaction with livestock. We also identify any potential gaps in the knowledge base which require future research.

DETERMINING FACTORS FOR LIVESTOCK PREDATION

Carnivore-livestock conflict has driven human-carnivore conflict since the domestication of animals and needs to be addressed to secure the livelihood of farmers and conservation of predators (Minnie, Boshoff & Kerley, 2015). Unfortunately, there are few data on the spatial distribution of livestock predation and the associated management responses by farmers (Minnie *et al.*, 2015). Ultimately, the primary cause of conflict is competition for the livestock between humans and predators.

Many ecological and biological variables can affect the likelihood of livestock predation. Factors such as the distance from water sources, distance from protected areas, elevation and surrounding vegetative cover may all play a role (Knowlton, Gese & Jaeger, 1999; Kolowski

& Holekamp, 2006; Dickman, 2010; Mattisson *et al.*, 2011; Thorn *et al.*, 2013; Minnie *et al.*, 2015). Thorn *et al.* (2013) concluded from their work in North West Province that the distance to protected areas is the most influential variable that determines the risk of predation. This could suggest that predator communities in protected areas that incorporate the surrounding farming matrix in their home ranges are more prone to conflict (Distefano, 2005).

Owing to the behaviour of many predators and the influence of prey size, cattle are less likely to be targeted as prey by predators such as cheetahs and leopards (Sinclair, Mduma & Brashares, 2003). Data on predation events depend on the farmers and their ability to keep accurate records of species affected and numbers lost, and their willingness to share the information. Some farmers are not always willing to report on predation, especially if they practice illegal predator control methods (L. Dumalisile pers. obs. 2017).

Diet and prey selection of predators in South Africa

Diet and prey selection of vertebrate predators are primarily driven by mass-related energy requirements and hence body size (Carbone, Mace, Roberts & Macdonald, 1999; Clements, Tambling, Hayward & Kerley, 2014). The threshold for obligate vertebrate carnivory is around 21.5 kg (Carbone *et al.*, 1999). Thus predators such as lions, leopards, spotted hyenas, cheetahs, and to a lesser extent free-roaming dogs, are suggested to predate on prey exceeding 45% of their body mass. It is therefore predicted that these predators are more likely to be livestock predators than smaller vertebrate predators (e.g. servals, side-striped jackals, Cape foxes, honey badgers and otters). While mass-related energy requirements and body size provide a framework to quantify the inclusion of prey weight categories into predator diet, other factors related to predator behaviour (e.g. ambush versus cursorial predators), prey behaviour (e.g. vigilance behaviour), predator morphology, and habitat requirements related to hunting or escape can all affect prey selection (Kruuk, 1986; Clements, Tambling & Kerley, 2016). Furthermore, factors like prey catchability, which is related to habitat characteristics (Balme, Hunter & Slotow, 2007) and prey vulnerability (Quinn & Cresswell, 2004) are key factors affecting prey selection (and hence diet) of predators. Therefore, the inclusion of

livestock in predator diets will be affected by predator distribution, predator density, predator size, predator hunting behaviour, prey behaviour, prey vulnerability, prey catchability, and density of natural prey.

Carnivore diets estimated from scat analysis alone should be viewed in the context of the biology of the predator. This is because some predators will scavenge and include carrion in their diet, which was not necessarily killed by the predator. So not all predators that eat livestock (as determined from scat analyses) kill livestock. Scat analysis should therefore always be kept in context of other evidence such as direct observations.

While there is a rich body of research investigating the prey preference and selection in South African carnivores (e.g. Hayward & Kerley, 2005; Hayward, 2006; Hayward *et al.*, 2006a; Hayward, O'Brian, Hofmeyr & Kerley, 2006b, Clements *et al.*, 2014), little is known about carnivore diets in non-protected areas where predation of livestock would most likely occur (e.g. Forbes, 2011; Humphries, Tharmalingam & Downs, 2016). Several questionnaire-based studies have investigated the predation of livestock by carnivores (van Niekerk, 2010; Chase-Grey, 2011; Thorn *et al.*, 2013; Badenhorst, 2014). The consensus among interview-based studies suggests that carnivores often predate on livestock, which leads to retaliatory killing (Thorn *et al.*, 2012; Thorn *et al.*, 2013). In contrast, several studies have, using scat analysis, quantified carnivore predation in non-protected areas (livestock and game farms), where results often contradict questionnaire-based research (Chase-Grey, Bell & Hill, 2017). For example, in the Waterberg Biosphere (South Africa) and Vhembe Biosphere (Soutpansberg, South Africa) landowner interviews reported high livestock predation by predators (Swanepoel, 2008; Chase-Grey, 2011), while scat analysis and GPS located kills found no livestock in leopard diet (Swanepoel, 2008; Chase-Grey, 2011; Chase Grey *et al.*, 2017). Therefore, there appears to be a mismatch between questionnaire-based research and carnivore diet quantified based on scat analysis and GPS located kills. Predators usually select wild species over domestic stock, but if natural prey are scarce, predators may increase livestock in their diet (Schiesl-Meier, Ramsauer & Gabanapelo & Koenig, 2007). The prevalence of livestock predation in a selection of predators for which data are available is reported in the species accounts below, while information on the remaining predators is provided in Table 9.1.

Table 9.1. Predators (excluding black-backed jackal and caracal) implicated in livestock predation in South Africa.

Species		Evidence				Frequency		Financial implications		Main activity time		Source of information	
Species	Species predated	Strong	Weak	Common	Local, isolated but can be substantial	Mostly nocturnal	Norton et al., 1986; Swanepoel, 2008; Hayward & Slotow, 2009, Martins et al., 2011; Minnie et al., 2015;						
Leopard	Cattle (calves), sheep, goats	Strong	Common	Local, isolated but can be substantial	Mostly nocturnal	Norton et al., 1986; Swanepoel, 2008; Hayward & Slotow, 2009, Martins et al., 2011; Minnie et al., 2015;							
Lion	Cattle, sheep, donkeys, horses	Strong	When out of protected area - rare	Local, isolated but can be substantial	Nocturnal and crepuscular	Hayward & Slotow, 2009; Butler, 2000							
Cheetah	Cattle (calves), sheep	Strong	Rare in SA	Local, isolated but can be substantial	Diurnal, crepuscular activity pattern with 62% diurnal	K. Marnewick Pers. Obs. 2017; Wilson, 2006							
Serval	Sheep (lambs)	Weak	Rare	Low	Nocturnal and crepuscular	Thorn et al., 2012; Griffiths, 2015							
African wild cat	Sheep, goats (juveniles)	Strong	Rare	Low		Smuts, 2008; Lutchminarayan, 2014							
Black-footed cat	?	?	?	?	Nocturnal	No published information located							
Spotted hyena	Cattle, goats	Strong	Rare	Low, but can be locally substantial	Nocturnal but flexible	Parker, Whittington-Jones, Bernard & Davies-Mostert, 2014							
Brown hyena	Goats, sheep	Weak	Rare	Low	Nocturnal	Skinner, 1976; Mills, 1990							
Aardwolf	Carcasses of various species	Weak	Rare	Low	Nocturnal but flexible	Anderson, 2013							
African wild dog	Sheep, goats, seldom cattle	Strong	Rare	Local, isolated but can be substantial	Strictly crepuscular	Davies & Du Toit, 2004; Woodroffe et al., 2005; Hayward & Slotow, 2009; Lyamuya, Masenga, Fyumagwa & Røskaft, 2014							
Domestic dog	Sheep, goats, seldom cattle, mostly scavenge	Strong	Unknown	Low	Mostly diurnal	Butler & Toit, 2002; Lutchminarayan, 2014							
Cape fox	Sheep, goats	Strong	Rare	Low	Nocturnal	Bester, 1982; Stuart, 1982; Hodkinson et al., 2007; Edwards et al., 2015							

Bat-eared fox	None found?	?	Rare if true	Low if true	Crepuscular and nocturnal	Lutchininarayan, 2014; Edwards et al., 2015
Honey badger	Sheep	Strong	Rare	Low	Nocturnal but flexible	Begg et al., 2016; Do Linh San, Begg, Begg & Abramov, 2016; PMF, 2016
African clawless otter	Sheep	?	Rare	Low	Nocturnal to crepuscular in places	Anecdotes; PMF, 2016
Chacma baboon	Goats, sheep	Strong	Rare to locally abundant (see Butler 2000, for Zimbabwe)	Local, occasional but can be substantial and adds to infrastructure or crop damages	Diurnal	Bolwig, 1959; Hall, 1962; Dart, 1963; Butler, 2000; Tafani et al., in prep.
Bushpig	Sheep	?	Rare	Low	Nocturnal	Seydack, 1990; PMF, 2016
Birds (eagles, owls, corvids, gulls)	Sheep, goats		Rare	Low	Diurnal or nocturnal (owls)	Davies 1999; Botha, 2012; Lutchminarayan, 2014; Visagje & Botha, 2015; PMF, 2016
Python	Calves, goats, dogs	Strong	Rare	Rare	Diurnal	Hodkinson et al., 2007
Crocodiles	Sheep, goats, donkeys, dogs	Strong	Rare and localised	Low but can be severe for poor communities		Guggisberg, 1972; Fergusson, 2000

Strong = supported by recognised peer reviewed publications or reviews by credible sources,
Weak = not supported by peer reviewed publications or reviews by credible sources, some anecdotes
Common = published data showing frequent reports as indicated in publications or expert opinion.
Rare = no data showing frequent occurrences of predation. Evidence through anecdotes.

Activity patterns of predators and how this affects livestock predation

Predator activity patterns vary with species and have evolved through a diverse range of selection forces. Activity patterns of predators are potentially influenced by a number of aspects such as direct or indirect competition with other predators (e.g. Saleni *et al.*, 2007; Hayward & Slotow, 2009; Edwards, Gange & Wiesel, 2015; Swanson, Arnold, Kosmala, Foster & Packer, 2016; Dröge, Creel, Becker & M'soka, 2017), or the activity patterns of their prey (e.g. Hayward & Slotow, 2009). Not all predators are nocturnal or active at the same time. Some such as African wild dogs, chacma baboons, crocodiles, and raptors (besides owls) are diurnal, and therefore pose a risk during the day. Wild ungulates' perceived risk of predation (i.e. the landscape of fear) can affect resource use and activity budgets (Brown, Laundre & Gurung, 1999). Livestock, however, although able to perceive the risk of predation (Shrader, Brown, Kerley & Kotler, 2008) cannot do much to reduce it. They are managed and can only avoid predation if managed appropriately (see

Chapter 6). To avoid or reduce predation on livestock it is, therefore, crucial to understanding the activity patterns of local predators (See Figure 9.1, Table 9.2). Putting livestock indoors, or in protected kraals at night may protect them against nocturnal predators, while having herdsmen or guard animals may help during the day (see Chapter 6). Although most animal species have a "baseline" activity pattern, a deviation in behaviour from the baseline occurs due to the interaction with their environment (Snowdon, 2015). Large carnivores have different abilities to adapt. Those with high behavioural plasticity and flexible ecological traits are those that recover quickly from depletion and which are more inclined to live close to humans (Cardillo *et al.*, 2004). For example, spotted hyenas change their demographic structure, social behaviour, daily activity rhythm, and space use in response to increased livestock grazing (Boydston, Kapheim, Watts, Szykman & Holekamp, 2003).

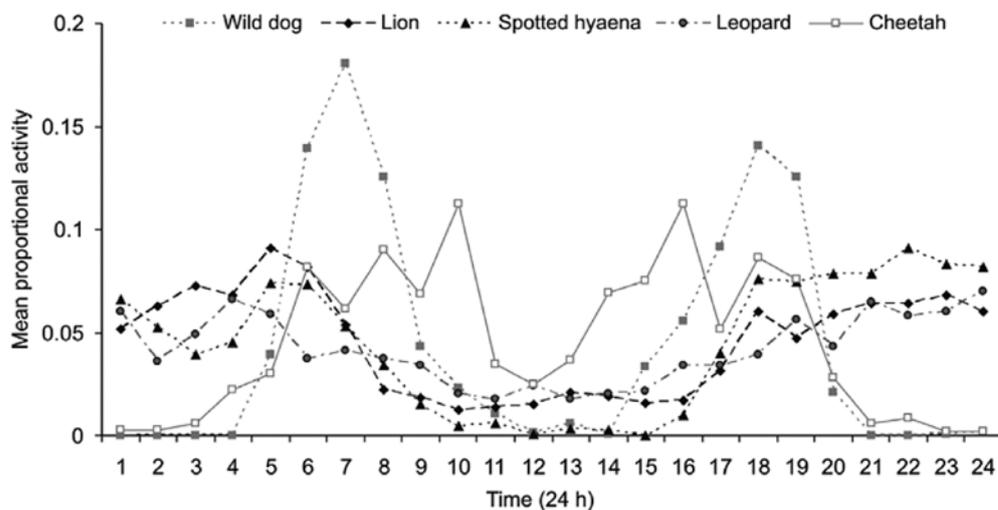


Figure 9.1. Daily mean activity pattern (proportion an animal's daily activity that occurs in each hour) of all five members of Africa's large predator guild. (From Hayward & Slotow, 2009; Reproduced with permission of SAWMA).

Social structure of predators and its influence on livestock predation

The influence of home range size and territoriality on predation

An animal's home range is defined as "the area about its established home which is traversed by the animal in its normal activities of food gathering, mating and caring for young" (Burt, 1943). Predators have large home ranges; this often draws them into conflict with people (Treves & Karanth, 2003; Graham, Beckerman & Thirgood, 2005). For predators, home range size is influenced by several factors, including the spatial distribution of available prey (Hayward, Hayward, Druce & Kerley, 2009), metabolic needs, and diet (Gittleman & Harvey, 1982). For example, obligate vertebrate carnivores (in other words, those most likely to come into conflict with livestock farmers) tend to have the largest home ranges (Gittleman & Harvey, 1982), which complicates their management.

The spatial ecology of predators is based on their need to fulfil physiological, ecological and social requirements (Owen-Smith & Mills, 2008). These requirements are met with a combination of habitat suitability (Ogutu & Dublin, 2002), resource availability (Owen-Smith & Mills, 2008) and social dynamics (Packer *et al.*, 2005; Loveridge *et al.*, 2009). Home ranges need to be sufficiently large to ensure access to resources such as food, water, shelter and access to breeding mates (De Boer *et al.*, 2010). Animals usually adjust their location in space until their requirements have been met (Abade, Macdonald & Dickman, 2014). Consequently, environmental disruptions can alter home range selection and subsequently, negatively affect the requirements of an individual or even a population (Packer *et al.*, 2005). Similarly, social disruptions (e.g. caused by the excess removal of males) can alter the social organisation of predator species, which can potentially increase the roaming behaviour of individuals, or lead to an influx of new animals (Balme, Slotow & Hunter, 2009). Both these scenarios can inadvertently cause greater movement of predators, both from within a protected area to the outside or from outside in, which can potentially increase conflicts with livestock.

Home range sizes vary between animals of the same species, and this can be considerable, demonstrating the individuals' ability to adjust resource use in response

to local conditions (Moorcroft & Lewis, 2013). The availability of prey influences a predator's movement within its home range: for example, when prey are scarce, African wild dog packs traverse their entire home range every 2-3 days, whereas during periods of greater prey availability, foraging efforts are much more restricted (Frame, Malcom, Frame & van Lawick, 1979). Similarly, home ranges of lion prides in the dry areas such as the Kalahari – a prey-scarce ecosystem – are 6-10 times larger than in most other areas where prey are substantially more abundant (reviewed in Hayward *et al.*, 2009). These variations have an important bearing on predator-livestock conflict, especially where human activities, such as habitat alteration, or the exclusion or exploitation of natural herbivores, have led to reductions in the prey resource base for predators, resulting in the likelihood of attacks on livestock (Graham *et al.*, 2005).

Seasonal variation in the spatial organisation may also influence the degree and spatial scale of predation. For example, for about 3 months each year during the denning season (which, in South Africa, takes place in mid-winter); African wild dogs occupy only a portion (average 50–260 km²) of their annual home range (average 150–2,460 km²; Hunter & Barrett, 2011). During this time, it is assumed that local impacts on prey can be more pronounced. However, a study of this phenomenon in the Lowveld of Zimbabwe suggests that these concerns are unfounded in some situations (Mbizah, Joubert, Joubert & Groom, 2014).

In a global review of human-predator conflicts, Graham *et al.* (2005) found that a third of the variance in the percentage of livestock (and game) prey taken by predators was explained by a combination of net primary productivity and predator home range, where percentage of prey was inversely related to both productivity and home range. The influence of home range on predator density is the likely mechanism affecting this pattern (Graham *et al.*, 2005), where larger home ranges tend to belong to larger species occurring at lower densities.

Carnivore home ranges also vary greatly in their level of exclusivity, from loosely defended home ranges to heavily defended, mutually exclusive territories. A territory may be defined as "a fixed space from which an individual, or group of mutually tolerant individuals, actively excludes competitors" (Maher & Lott, 1995). These variations have important consequences

for demography, and consequently for ecological relationships, including predator-prey dynamics and management strategies to influence these. For example, territorial animals such as female mustelids tend to have mutually exclusive ranges, limiting the overall population density and mobility across a landscape. Disruptions in population spatial structure (for example, removal of resident individuals) may have unpredictable effects on home range placement. Highly territorial species are excellent candidates for non-lethal methods of conflict management that allow for the presence of resident individuals that do not kill livestock themselves, but keep losses locally low by excluding conspecifics (Shivik, Treves & Callahan, 2003). Small home ranges may indicate high predator density and therefore high predation frequency; large home ranges may lead to regular contact with prey “patches” (Graham *et al.*, 2005), both these scenarios can exacerbate conflict.

Social organisation and its influence on predation

Predator social organisation has an important bearing on prey selection (Clements *et al.*, 2016) and hence livestock predation risk and, in turn, the mechanisms by which conflict can be mitigated. Predators can be broadly classified as group-living or solitary, where group-living species are those in which individuals regularly associate together and share a common home range, while solitary species forage alone (Gittleman & Harvey, 1982). A comparison between solitary leopards and social African wild dogs neatly exemplifies this point: leopards are spaced out individually, and predation incidents typically involve just one individual within a population – and not all individuals. Therefore, there may be a problem in one place and not another depending on an individual. In contrast, African wild dog packs hunt together, and therefore the entire pack would be responsible for predation. They, however, have large home ranges, so effects on predation are not localised.

Related to this is the fact that group-living predators tend to be more visible when they encounter humans and their livestock and are therefore less tolerated. Conversely, solitary predators tend to be more cryptic. Consequently, human perceptions of the predation impact of group living predators may be exaggerated (Kruuk, 2002).

Density of predators and how it affects livestock predation

Management, land use practices, previous land use, and activity in neighbouring properties influence habitat quality and can play a significant role in determining the local density of predators (Balme *et al.*, 2009; Rosenblatt *et al.*, 2016). Alterations in landscape features and land use are key drivers of habitat degradation and fragmentation leading to declines in predator populations. This is particularly true for South Africa, where there has been a significant shift from livestock farming to game farming (Carruthers, 2008; Taylor, Lindsey & Davies-Mostert, 2016). Furthermore, as the viable habitat and resources available for predators decline with increasing human populations, the need for predator conservation and wildlife management efforts increases (Friedmann & Daly, 2004). For example, lions require large expanses of land (Schaller, 1972). For lions to survive and thrive, the land use must be restricted and dedicated to wildlife (see Ferreira & Hofmeyr, 2014). This can be in the form of game farming or protected areas. Although lions can cross through ill-maintained fences, if the habitat quality and food resources within the game farm or protected area are adequate, the likelihood of transgression into neighbouring areas is low.

There appear to be several mechanisms, not necessarily mutually exclusive, that drive predator densities. First, the conflict between landowners and carnivores is often reported in areas where land use is dedicated to consumptive wildlife utilisation or livestock production (Dickman, Hinks, Macdonald, Burnman & Macdonald, 2015). Such conflict often results in persecution that directly reduces carnivore densities, even when prey densities remains adequate to sustain high carnivore populations (Balme, Slotow & Hunter, 2010). For example, leopard densities in prey-rich game farming areas can be as low as 20% of potential densities (Balme *et al.*, 2010). In contrast, studies have highlighted that non-protected land can have equal or even higher carnivore densities than protected areas (Stein, Fuller, DeStefano & Marker, 2011; Chase-Grey, Bell & Hill, 2013; Swanepoel, Somers & Dalerum, 2015). Such high densities can be attributed to high prey biomass and or reduced intraspecific competition. For example, subordinate predators such as cheetahs maybe higher

densities in non-protected areas as there are fewer dominant predators such as lions (Marker-Kraus, 1996). However, such high carnivore densities can also be due to temporary immigration into these areas due to high local removal rates (Williams, Williams, Lewis & Hill, 2017). Secondly, prey populations in non-protected areas can be depleted due to poaching, habitat modification and game-livestock competition that could limit the density of carnivores (Rosenblatt *et al.*, 2016). Owing to the lack of density data for most species and all these variables affecting densities, we provide only general descriptive density estimates for each predator species (Table 9.2).

It can thus be concluded that predator density will most often be determined by prey density. As such,

we can also speculate that high natural prey biomass would ultimately also facilitate high livestock biomass (at least if both could co-occur). Under such conditions, we can further hypothesise that predation on livestock can be low when natural prey is high, possibly mediated through facilitation (e.g. at high livestock and natural prey availability, predators will choose natural prey) (Suryawanshi *et al.*, 2017). Alternatively, high natural prey (and hence high predator density) can induce high livestock predation, mediated through competition (Suryawanshi *et al.*, 2017). While studies investigating the relationship between predator density and livestock predation are few in South Africa, the pattern from elsewhere is not clear. Several studies have shown that

Table 9.2. Characteristics of the social and spatial organisation of predator species implicated in livestock conflicts in South Africa (Skinner & Chimimba, 2005).

Predator species	Social organisation	Group size	Territorial	Home range sizes (km ²)		Density (ind./100 km ²)
				Minimum	Maximum	
Leopard	Solitary	1-2	Yes	14.8	2182	0.62-15.63
Cheetah	Solitary females / male coalitions	1-5	Yes, males	24	1848	0.25-1
Serval	Solitary	1 or 1 + young	Yes	2.2	38	7.6
African wild cat	Solitary	1 or 1 + young	Yes	3.4	9.8	10-70
Lion	Group	1-30	Yes	150	4532	Up to 15
African wild dog	Group	1-50	Yes	150	>2000	Up to 60
Side-striped jackal	Group	1-7	Yes	0.2	4	0.07-1
Cape fox	Solitary	1-2	Yes, around den	9.2	27.7	
Feral domestic dogs	Solitary; group	?	?	1	4.6	?
Spotted hyena	Group	3 to 90+	Yes	9	>1000	2-35
Brown hyena	Solitary foragers	1 – 2	Yes	49	480	1.8-19.00
Chacma baboon	Group	10 to 200+	Yes	?	?	?
Honey badger	Solitary	1 or 1 + young	Yes	85	698	3-10
Bushpig	Group	1-5	Yes	3.8	10.1	3-50
Crocodile	Solitary	1	Yes	0.5	0.8	?

high natural prey densities can sustain higher predator densities, but with an increased risk of livestock predation (and more conflict) (e.g. snow leopards, Suryawanshi *et al.*, 2017). In contrast, several studies have highlighted that increased natural prey decreased predation on livestock (Meriggi, Brangi, Sacchi & Matteucci, 1996; Meriggi, Brangi, Schenone, Signorelli & Milanesi, 2011). However, many of these studies do not report on predator densities, which can be the driving factor in a variation of livestock predation and prey densities.

Dispersal of predators in South Africa

Dispersal occurs for a number of reasons. A dispersing individual is often alone, hungry, young and relatively inexperienced, and can go a long way out of its normal familiar range. These are dispersers, typically sub-adults perhaps, who have left their natal prides or packs and looking for a new home. Alternatively, dispersers could be old, weak and hungry individuals who have been pushed out of prides, packs or territories. Dispersing individuals can be responsible for important predation on livestock.

Movement of predators through is influenced by several factors that include availability or quality of food resources, predator avoidance and other environmental conditions (van Moorter *et al.*, 2013; Kubiczek, Renner, Böhm, Kalko & Wells, 2014). The way animals move and use space influences interactions with resources, thus affecting ecosystem processes, e.g., predation (Böhm, Wells & Kalko, 2011). We, therefore, need to know the identity and location of populations of predators. From this, we can perhaps predict dispersal patterns and mitigate against them. For instance, African wild dogs disperse, often from protected areas, in a predictable manner to form new packs. Pre-empting this with community engagement programs is recommended (Gusset *et al.*, 2007).

Many predators can move over large distances, especially when dispersing. Some examples include African wild dogs, which have on been recorded dispersing over 80 km (Davies-Mostert *et al.*, 2012). These African wild dogs moved through protected areas, farmland, and communal living areas and along roads. All these situations, including private, protected areas, provide opportunities for conflict. Similarly, a sub-adult male leopard was recorded dispersing 352 km from

his natal range (Fattebert, Dickerson, Balme, Slotow & Hunter, 2013). This highlights the vast distances carnivores can disperse, which could bring them into conflict with multiple land users.

Geographical distribution of livestock predation events in South Africa

There is no database, and few data, on the distribution of livestock predation events within South Africa (Minnie *et al.*, 2015). Even within individual provinces, there are no published data available. We can therefore only provide a brief overview for each province. The type of livestock farmed influences the type of predator most likely to attack; larger predators are known for taking large domestic species, whereas smaller predators take a greater proportion of small to medium-sized livestock, such as sheep and goats (Sangay & Vernes, 2008). This results in the trend that the southern provinces tend to be dominated by small predators, such as jackals, while large predators are an issue in the north.

In communal farmland areas in the Grassland, Savanna and Succulent Karoo biomes the main livestock predators are reported to be caracals, black-backed jackals, but also domestic dogs and leopards. Leopards were only seen as a threat in the Savanna. Other predators were perceived as much less of a threat (Hawkins & Muller, 2017).

In the Eastern Cape Province, there are some data on vegetation-type specific predation by leopards in the Baviaanskloof Mega-Reserve (Minnie *et al.*, 2015). Here leopards were reported to prey on sheep and goats. Banasiak (2017) reported that re-introduced lion, leopard, cheetah and brown and spotted haeyna were responsible for livestock attacks (predominantly sheep and cattle) in the Eastern Cape, these predators being escapees from local reserves. Verreaux's eagles *Aquila verreauxii* are also implicated in the killing of lambs, but direct evidence of this is often lacking (Visagie & Botha, 2015). During periods of extreme drought, Cape vultures *Gyps coprotheres* have been reported killing newborn lambs in a weak condition, particularly if ewes leave them alone, and African crowned eagles *Stephanoaetus coronatus* come into conflict with stock farmers (Hodkinson, Snow, Komen & Davies-Mostert, 2007).

Van Niekerk (2010) studied the economic losses attributed to small stock predators in the Western Cape

Province and concluded that although predation losses were relatively low for the whole province, areas such as the Central Karoo, where small stock farming is the main agricultural activity, experienced high losses due to predation by (besides black-backed jackals and caracals), leopards, chacma baboons, crows and vagrant dogs. Brackowski *et al.* (2012a) studied the diet of caracal in the George and Vleesbaai regions, and reported that although no livestock were detected in the scats of this predator, the local conservation organisation (CapeNature) had issued approximately 60 hunting permits for caracal to farmers in the Vleesbaai regions, suggesting that caracal-livestock conflict existed, even though not formally recorded.

Chardonnet *et al.* (2010) reported that occupants of some villages bordering the Kruger National Park (Mpumalanga and Limpopo Provinces) were responsible for the killing of lions supposedly responsible for killing cattle. To rectify the matter, it sufficed that the villagers remove cattle from within 500m of the park fence. However, elsewhere in Mpumalanga, van Niekerk (2010) reported that farmers attributed livestock losses to predation by black-backed jackals and caracals.

Personal communications from officials within the Gauteng Department of Agriculture and Rural Development (GDARD) to L. Dumalisile revealed that very few predator-livestock conflict events were reported by farmers in the Gauteng Province; only through permit applications for hunting Damage Causing Animals (DCA's) are records of conflicts received. Because of this, there are no reliable data on predator-livestock conflicts, except for some unconfirmed complaints from some farmers received by the General Investigations Unit of the Department that reported unconfirmed leopard kills (L. Lotter. pers. com. 2017).

In North West Province, Thorn *et al.* (2012) reported that farmers attributed 20% of predation to caracals, 41% to jackals, 15% to leopards, 12% to brown hyenas, 7% to cheetahs, 3% to spotted hyenas, with one attack being attributed to servals.

Rowe-Rowe (1992) provided some information on predation in KwaZulu-Natal. He listed African wild dogs emanating from Hluhluwe-iMfolozi Park as an occasional source of livestock predation. Incidents of predation on sheep and calves by brown hyena have been reported from the northern KwaZulu-Natal Midlands. Predation on

cattle calves and goats by spotted hyenas are common in northern KwaZulu-Natal around the Hluhluwe and Mkuze areas adjacent to major reserves such as Hluhluwe-iMfolozi Park, Mkuze Game Reserve, and Phinda Private Game Reserve. Retaliatory hunting of spotted hyenas through trophy hunting has increased dramatically in the last 9 years, potentially causing edge-effect related population declines within protected conservation areas (Hunnicut, pers. obs. 2017). Lions that leave protected areas often kill livestock. Ezemvelo KZN Wildlife assists in destroying such problem lions if needed. Leopards occasionally kill livestock in KwaZulu-Natal (Ferguson, 2006).

In the Northern Cape Province, Jansen (2016) reported that leopards were the main predators of goats near Namaqualand National Park. Another study in the Namaqualand (Paulshoek) found that apart from black-backed jackals and caracals, Cape foxes, Verreaux's eagles, black crows *Corvus capensis*, leopards, chacma baboons, African wild cats *Felis silvestris*, peregrine falcons *Falco peregrinus*, spotted eagle-owls *Bubo bubo* and bat-eared foxes *Otocyon megalotis* were responsible for livestock losses (Lutchminarayan, 2014). Cape and lappet-faced vultures *Torgos tracheliotus* may sometimes kill new-born lambs, particularly if ewes leave these alone, and Verreaux's and martial eagles *Polemaetus bellicosus* sometimes come into conflict with stock farmers in the Northern Cape (Hodkinson *et al.*, 2007).

In Limpopo Province, leopards remain the most important predator in livestock and game farming conflict (Pitman *et al.*, 2017). For example, leopards accounted for 68% of permits issued to nuisance wildlife in Limpopo Province during 2003-2012 (Pitman *et al.*, 2017). Permits issued for other nuisance carnivores during 2003-2012 include brown hyenas (3%), black-backed jackals (2%), caracals (2%), cheetahs (0.5%), and spotted hyenas (0.5%) (Pitman *et al.*, 2017). The majority of leopard mortality events due to problem animal removal were often in prime leopard habitat (Pitman, Swanepoel, Hunter, Slotow & Blame, 2015), which poses a conservation concern to leopard population persistence and connectivity (Swanepoel, Lindsey, Somers, van Hoven & Dalerum, 2014; Pitman *et al.*, 2017).

Most predator-livestock conflicts recorded for the Free State involve predation by black-backed jackals and caracals (e.g. van Niekerk, 2010).

A survey of 277 communal livestock farmers found that small stock experienced greater predation compared to large stock. However, predation did not differ between the three biomes within four provinces (Northern Cape, Eastern Cape, Limpopo and Mpumalanga; Hawkins & Muller, 2017). Losses to predation within this sample over the last 5 years ranged from extremely low (0 to 4% losses of cattle, 2% for sheep and goats) to moderate (10 to 20% for sheep and goats) based on both records and estimates of herd counts. The moderate losses of sheep and goats were comparable with those reported by van Niekerk (2010) for commercial farmers. For communal farmers, no biotic and abiotic variables (rainfall, biome, vegetation type) or management strategies (type and number of non-lethal livestock protection method, distance to nature reserve or water body) emerged as clear drivers of livestock loss (Hawkins & Muller, 2017).

SELECTED SPECIES ACCOUNTS

While lion, African wild dog and spotted hyena livestock predation may be restricted to the areas adjacent to protected areas and therefore remain relatively limited in South Africa, species like leopards, cheetahs, brown hyenas and chacma baboons can contribute locally to livestock losses. Here, we review the ecology of those predators in the context of livestock predation. Because only anecdotal evidence exists for the other species incriminated by South African farmers, they will only be briefly reviewed here and are summarised further in Table 9.1.

Lion

The dominant prey species of lions are generally divided into three categories based on body weight: small, ≤ 100 kg – warthog *Phacochoerus africanus* and impala *Aepyceros melampus*; medium, 100-230 kg for example blue wildebeest *Connochaetes taurinus*, greater kudu *Tragelaphus strepsiceros* and plains zebra *Equus quagga*; and large, ≥ 230 kg, for example buffalo *Syncerus caffer* and eland *Tragelaphus oryx* (Clements *et al.*, 2014). Water-dependent grazers, such as wildebeests and plains zebras, tend to remain near open surface water during the dry season (Smit, Grant & Devereux, 2007). Rainfall patterns in savanna systems have a direct impact not only on the available surface water but also on vegetation growth (du Toit, 2010). Thus, when rainfall patterns alter,

the distribution of plains zebras and wildebeests will be affected by available graze (Owen-Smith, 1996). Browsers obtain most moisture from their diet, thus making them less water dependent. Consequently, due to the feeding behaviour of browsers in savanna woodlands, the rate of encounter with lions is reduced.

In South Africa, the rate of livestock offtake by lions is relatively low in comparison to other African countries (Kissui, 2008). This, in part, is due to the fencing policies in South Africa. Natural populations of lions are found in the Kgalagadi Transfrontier Park and Kruger National Park, where incidences of lion and livestock interactions are reported adjacent to the park boundaries (e.g. Funston, 2011). This is often a consequence of dispersal, with movement out of the protected area towards areas with livestock.

Lions are nocturnal with peak activity periods at dusk and dawn. During daylight, lions rest. Other predators adjust their activity to avoid competition with this apex predator. Similarly, prey species adapt their behavioural patterns according to lion peak activity time (Saleni *et al.*, 2007, Tambling *et al.*, 2015). In regards to livestock practices, having animals in corrals between dusk and dawn reduces the likelihood of predation by lions.

In addition to ecological factors, social dynamics also influences lion home range metrics to varying degrees (Heinsohn & Packer, 1995). The home ranges of large prides in optimal patches may be smaller than expected, and the converse may be true for smaller prides in less productive areas. Thus, the number of adult females within a pride seems to influence the quality of the territory and may influence its relative size. Finally, anthropogenic influences could influence the movements and thus



Lion *Panthera leo*. Photo: Eugen Tulleken.

home ranges of lions. For example, mortalities due to human-lion conflict (Packer *et al.*, 2005), trophy hunting (Davidson, Valeix, Loveridge, Madzikanda & Macdonald, 2011) and bushmeat snaring (Lindsey & Bento, 2012) all influence home range size.

Movement over the landscape by predators varies according to the social structure and interactions with other members of the same species (Heinsohn & Packer, 1995). With regards to lions, both male and female sub-adults leave or are chased out of the pride due to social pressures. Young sub-adult females disperse from a territory when the pride social structure becomes unstable, such as when resources are constrained. Sub-adult males, however, disperse or are driven out of the pride for reproductive reasons. Although this behaviour is natural, this can become challenging to management on small reserves or areas that are surrounded by human communities and livestock activity. For this reason, it is critical for reserve management to practice good reproductive management in the form of contraceptive implants and relocating sub-adults (Miller *et al.*, 2013).

Spotted hyena

Spotted hyena clans live in a “fission-fusion” society in which members often travel and hunt alone or in smaller groups, joining a clan only to defend the territory and at a communal den site, or to hunt larger prey species (Smith, Memenis & Holekamp, 2007). The core of a spotted hyena clan is composed of a matrilineal group composed of closely related females and their offspring (Kruuk, 1972a). Males disperse from the clan at sexual maturity, between the ages of 2 and 6 years and will try to join non-natal clans (Boydston *et al.*, 2005).

Spotted hyenas are territorial, using vocal displays, scent marking, latrine sites, and border patrols to establish and defend territories (Kruuk, 1972a; East & Hofer, 1993; Mills & Hofer, 1998). Territory size can vary based on prey densities, from 40 km² in the Ngorongoro Crater in Tanzania (Kruuk, 1972a) to 1000 km² in parts of the Kalahari (Mills, 1990). Individuals are not limited to their clan’s territory and often make long-distance foraging trips to find food (East & Hofer, 1993).

Spotted hyenas are efficient hunters, able to kill animals several times their size, with a success rate of 25-35% (Kruuk, 1972a; Mills, 1990). In ecosystems with high prey densities, such as the Maasai Mara in



Spotted hyenas *Crocota crocuta*. Photo: Colin Grenfell.

Kenya, hyenas kill as much as 95% of the food they eat (Cooper, Holekamp & Smale, 1999). They mostly consume medium to large ungulates weighing up to 350 kg (Hayward, 2006). However, they are also capable of effectively hunting sizeable animals such as giraffe *Giraffa camelopardalis giraffa* and buffalo (Kruuk, 1972a; Cooper, 1990; East & Hofer, 1993; Holekamp, Smale, Berg & Cooper, 1997).

As opportunistic hunters, spotted hyenas tend to hunt the most abundant prey species and do so either solo or in groups (Kruuk, 1972a; Cooper, 1990; Höner, Wachter, East, Runyoro & Hofer, 2005). In addition to hunting, spotted hyenas readily scavenge (Kruuk, 1972a; Cooper, 1990; Mills, 1990; East & Hofer, 1993). In areas where prey densities are much higher, the cost of carrion consumption outweighs the benefits, and spotted hyenas underutilise this feeding strategy compared to other areas with lower prey densities where livestock predation is more likely (Cooper *et al.*, 1999). However, in areas where native prey species have largely been extirpated or displaced by extensive human settlements, such as northern Ethiopia, spotted hyenas can exclusively utilise anthropogenic food leftovers (Yirga *et al.*, 2012).

Limited work has been done to quantify livestock conflict with spotted hyenas in South Africa. However, much like leopards, they are commonly found outside of protected areas in some areas such as Mkuze, KwaZulu-Natal. Spotted hyenas utilise livestock such as cattle and goats in areas adjacent to parks with spotted hyena populations in KwaZulu-Natal (Mills & Hofer, 1998).

Though spotted hyenas do kill livestock, they are also often wrongly accused and persecuted due to their nature of scavenging on carcasses of livestock that either died of natural causes or were killed by other carnivores. This leads to the common persecution of spotted hyenas by poisoning carcasses of livestock (Mills & Hofer, 1998; Holekamp & Dloniak, 2010).

Despite the lack of work done in South Africa on livestock conflict, many studies in East Africa have investigated spotted hyena interactions with domestic animals. In the Maasai Steppe in Tanzania spotted hyenas and leopards favoured smaller livestock such as goats, sheep, and calves (also dogs), whereas lions select cattle and donkeys (Kissui, 2008). Temporal patterns of attacks showed that lions were more likely to attack grazing animals during daylight, whereas spotted hyenas and leopards were almost exclusively predating at night. Slight seasonal variations were exhibited by lions and spotted hyenas, where attacks on livestock from both species increased during the wet season (Kissui, 2008).

Leopard

Leopards have the widest geographic distribution of all felids and achieve this by their adaptability (Boitani *et al.*, 1999) and varied diet (Hayward *et al.*, 2006a). They are solitary and associated with rocky hills, mountains, forests, and savannas, but they also occur in deserts where they are restricted to the watercourses (Nowell & Jackson, 1996). Leopards are widespread outside formal conservation areas in South Africa (Swanepoel, 2008). Conflict with leopards is common in livestock and game ranching areas. This is made worse by their large home ranges, (159 to 354 km² or larger) (Swanepoel, 2008). Negative attitudes towards leopards, caused by this conflict, are normally the reason for leopard persecution (Swanepoel, 2008; Swanepoel, Lindsey, Somers, van Hoven & Dalerum, 2013).

The leopard is the most widespread large carnivore in South Africa and is often found on non-protected areas, and so several studies have investigated leopard diet (Balme, Lindsey, Swanepoel & Hunter, 2014). Historically leopards were believed to be a major predator of livestock, especially in the Cape Province. For example, the Ceres Hunting Club attributed between 44% (1979) and 16% (1980) of sheep losses to leopard (Conradie, 2012). Similarly, Norton, Lawson, Henley & Avery (1986)

reported a 1.5% occurrence of domestic stock in leopard scats. These predation events translated to an average of 620 small stock that were believed to be killed by leopards in the Western Cape, resulting in the removal of 26 leopards per year on average (1977-1985; Chief Directorate Nature and Environmental Conservation, 1987). In areas where small ruminants dominate livestock (e.g. goats and sheep; Western Cape), leopards appear to incorporate livestock more often into their diet, especially in areas where native prey animals are depleted (Mann, 2014; Jansen, 2016). For example in the Little Karoo (Western Cape) livestock (mainly goats, cattle and feral donkeys) contributed to 10% of prey biomass consumed by leopards (Mann, 2014). In the Namaqualand, there was a stark contrast between leopard diet in protected areas (livestock 3.5%) of biomass consumed, mainly goats) compared to farmland (livestock 40.4% biomass consumed with 22.8% goats and 14.8% sheep) (Jansen, 2016). In the Cederberg area livestock comprised around 3.5% to 3.8% of leopard diet (Martins, 2010; Martins, Horsnell, Titus, Rautenbach & Harris, 2011), while in the Baviaanskloof Provincial Nature Reserve livestock comprised around 5% of leopard diet (goats and sheep; Ott, Kerley & Boshoff, 2007). Similarly, livestock (cattle) comprised around 5.3% of the biomass consumed by leopards in the southwestern Cape (Brackowski, Watson, Coulson & Randall, 2012b).

In the Soutpansberg area (Vhembe Biosphere, northern South Africa) several studies have found no livestock in leopard diet (Stuart & Stuart, 1993; Schwarz & Fischer, 2006; Chase-Grey *et al.*, 2017), despite the fact that livestock are abundant in these areas (Chase-Grey, 2011). In contrast, some studies from the Waterberg area, have found that livestock (largely cattle) contributed to between 2.5% and 3.9% of leopard diet (Grimbeek, 1992), while others studies failed to detect any livestock in the diet of leopards in this area (Swanepoel, 2008; Jooste, Pitman, van Hoven & Swanepoel, 2012; Pitman, Kilian, Ramsay & Swanepoel, 2013).

African wild dog

African wild dogs are endangered, with a global population estimate of 6600 (Woodroffe & Sillero-Zubiri, 2012). Populations have declined markedly over the past several decades, with limited populations surviving in South Africa (Davies-Mostert, Mills, Macdonald,

Hayward & Somers, 2009). African wild dogs are limited by competition with larger, more abundant carnivores in protected areas, but are still at low densities outside protected areas owing to direct human persecution.

Livestock predation by African wild dogs is low. However, it can be locally severe with surplus killing. For example, in Kenya in areas with abundant livestock, African wild dog predation was low (ca one attack per 1000 km² per year), and the costs of tolerating the African wild dogs were low (US \$3.40/African wild dog/year). This occurred even where there were low densities of wild prey (Woodroffe, Lindsey, Romañach, Stein & ole Ranah, 2005). The same has been found in mixed farmland, private reserves and game farms in the Waterberg Biosphere Reserve in South Africa, where the diet of African wild dogs was determined through scat analysis. No livestock remains were found in the scats, despite the fact that dogs roamed over some livestock farms (Ramnanan, Swanepoel & Somers, 2013). In Botswana, Gusset *et al.* (2009), using questionnaires, found African wild dogs responsible for 2% of reported cases of predation. Despite this, ranchers interviewed in South Africa and Zimbabwe ranked African wild dogs as the least-liked predator, disliked even more than spotted hyenas, jackals, lions and leopards (Lindsey *et al.*, 2005b). Although African wild dogs kill livestock at lower levels than some other predators, they are still killed in retaliation for incidents of predation (Fraser-Celin, Hovorka, Hovork & Maude, 2017).

Chacma baboons

Baboons are large, widely distributed primates that are capable of living in a variety of habitats, even those heavily encroached or transformed by human activities (Altmann & Altmann, 1970; Swedell, 2011). The adaptability of baboons is mostly a function of their generalist diet, dexterity and scope of social learning (Swedell, 2011). While baboons' diet is composed predominantly of plant matter (Altmann & Altmann, 1970; Swedell, 2011), predatory behaviour has been described in most baboon species and is best known in olive baboons *Papio anubis* in central and western Africa (Dart, 1963; Strum, 1975; Hausfater, 1976; Hamilton & Busse, 1978; Strum, 1981; Davies & Cowlshaw, 1996). Potential wild prey species include various small ungulates, such as Thomson's gazelles *Gazella thomsoni*,



Chacma baboon *Papio ursinus*. Photo: Cath Shutte.

Grant's gazelles *Gazella granti*, dik-diks *Rhyncotragus kirki*, steenboks *Raphicerus campestris*, impalas, other primates (e.g. vervet monkeys, *Cercopithecus aethiops*), small mammals (African hares, *Lepus capensis*, and several rodent species), birds, reptiles and amphibians. Prey are opportunistically encountered while foraging on plants. There are, however, a few documented cases of systematic hunting, with adult males actively seeking and chasing prey (Harding, 1973; Strum, 1975; Strum, 1981). Strum (1981) found that the number of prey killed by a single olive baboon troop varied from 16 to 100 per year over a seven-year period in Kenya.

Baboon predation on livestock is seldom documented in scientific literature. According to farmers' surveys in Tanzania and Benin, olive baboons were responsible for, respectively, 0.8% (during a 12-month period, Holmern, Nyahongo & Roskaft, 2007), and 24.8% (between 2000 and 2007, Sogbohossou, de Longh, Sinsin, de Snoo & Funston, 2011) of all small-livestock losses recorded. Butler (2000) surveyed Gokwe communal farmers in Zimbabwe, who reported that chacma baboons killed more livestock than lions and leopards (52% losses attributed to chacma baboons representing about 125 kills over 3.5 years) but only targeted small livestock, thereby having less impact on farmers' livelihoods than larger carnivores. In South Africa, farmers also report that chacma baboons mainly target the young of small livestock including sheep and goats (Dart, 1963; Stoltz & Saayman, 1970). A recent survey on Central Karoo farms in South Africa reveals that since the year 2000 a small but an increasing number of farmers rank chacma

baboons as the top predator of small livestock on their farms, ahead of the two traditional carnivore species in the area viz. jackals and caracals (Tafani *et al. in prep*). Farmers reported mostly lamb losses, often with their abdomens having been ripped open and the skin rolled up to gain access to the stomach content (Tafani & O’Riain, 2017). However, despite these reported losses, Tafani *et al. (in prep)* reveal very low overall level of carnivory (wild or domestic) in the yearly diet of most troop members living on small livestock farms. Isotopic signatures of individuals show that only select adult males exhibit higher nitrogen levels that may reflect a higher proportion of animal protein in their diet (Tafani *et al., in prep*). This result requires further investigation to clarify the food sources (Tafani *et al., in prep*).

Predatory behaviour is highly variable between individuals and between troops. In various studies, mainly adult males (Strum, 1975; Hausfater, 1976; Hamilton & Busse, 1978; Strum, 1981; Davies & Cowlshaw, 1996; Butler, 2000) were involved in predation of wild or domestic prey; males were also the only ones recorded initiating complex hunting techniques (Strum, 1981). Additionally, prey sharing is limited and often an involuntary result of agonistic interactions (Hausfater, 1976). Behaviour acquisition through observational learning is thought to happen between individuals of the same troop. Strum (1981) observed this trend in the Gilgil troop, in which the proportion of all individuals engaging in predation increased with time. However, it generally remains a small contribution to their diet.

Baboons can learn quickly about the availability of new resources (Strum, 2010) and modify their daily routes (Hoffman & O’Riain, 2012) and foraging tactics (Strum, 2010; Fehlmann *et al.*, 2017a) accordingly. In the Karoo and Zimbabwe, farmers reported increased predation rates by baboons during drought periods (Butler, 2000; Tafani *et al., in prep*), suggesting that food scarcity may drive the behaviour. Most South African small-livestock farms are susceptible to droughts and rely on the provision of artificial water points (farm boreholes) where supplementary feed for livestock is also often provided when needed. It is likely that these resources attract baboons and bring them into close and regular contact with livestock – thus promoting opportunistic predation on lambs in particular (Tafani & O’Riain, 2017). Potential solutions to livestock predation by baboons

have yet to be researched and remain a challenge at the scale of extensive camps, and given baboons’ ability to habituate to many management techniques (Kaplan & O’Riain, 2015; Fehlmann, O’Riain, Kerr-Smith & King, 2017b). Currently, due to a lack of management advice specific to baboons, most farmers use lethal methods, in particular, cage capture with whole troops often being targeted in areas where losses are high (Tafani & O’Riain, 2017). Tafani *et al. (in prep)* suggest that culling whole troops is not appropriate, humane nor it is likely to be sustainable as new troops may move into vacated home ranges (Hoffman & O’Riain, 2012). While more research on livestock predation by chacma baboons is needed, identifying raiders (Strum, 2010) and improving the protection of livestock during critical periods of low biomass and lambing peaks, could reduce baboon’s opportunities of predation and allow for case-specific management (see Box 6.2, Chapter 6 for non-lethal management methods used in the urban areas of Cape Town).

Birds of prey and vultures

Some raptors occasionally predate on livestock (with a low conflict potential); lappet-faced- and Cape vultures may kill new-born lambs, particularly if the lambs are left alone (Hodkinson *et al.*, 2007).

Verreaux’s Eagles, especially immature birds, are known to take the lambs of smaller livestock (e.g. sheep and goats) and antelope as food (Hodkinson *et al.*, 2007). Boshoff, Palmer, Avery, Davies & Jarvis (1991) reported that juvenile domestic livestock comprised



Martial eagle *Polemaetus bellicosus*. Photo: Colin Grenfell.

3.4% of the diet of Verreaux's Eagles in the then Cape Province. This can lead to conflict with farmers. Verreaux's eagles regularly take carrion and are consequently often wrongly accused of killing livestock that were, in fact, killed by other predators or had died of natural causes (Botha, 2012).

In addition to Verreaux's Eagles, other species such as martial and African crowned eagles have been reported killing livestock and certainly can do so. Boshoff & Palmer (1979) reported that 8% of prey remains of adult martial

eagles comprised of domestic livestock, particularly young livestock. Similar to the abovementioned scenario with Verreaux's eagle, these birds readily scavenge and can be wrongly accused of killing livestock when they are observed scavenging from a carcass (Visagie & Botha, 2015). This may also apply to species such as the tawny eagle *Aquila rapax*, African fish eagle *Haliaeetus vocifer*, jackal buzzard *Buteo rufofuscus* and yellow-billed kite *Milvus aegyptius* who all readily scavenge from carcasses.

Box 9.1 Information gaps

There is a lack of a coherent predator conflict monitoring program across all provinces. We found few published data on predator conflict as recorded by the relevant provincial authorities. It is, therefore, difficult to quantify temporal and spatial trends in predator conflict. We suggest that possible avenues to address these are for provincial authorities to liaise with local academic institutions to develop and maintain relevant monitoring programs.

1. Predator research is still predominantly carried out in protected areas. For predator research to be relevant, it will have to be framed in the broader conservation issues faced by predators. Since the majority of predators in South Africa require large tracts of land and the majority of suitable habitat is often in private hands, it is essential to increase research in these non-protected landscapes. Furthermore, the main determinant of predator survival in non-protected areas is human wildlife conflict and tolerance; it is essential that research address these issues.
2. Controlled treatment studies investigating the effectiveness of mitigation actions is needed. There is a general lack of research investigating the effectiveness of mitigation actions. These controlled treatment studies will be fundamental in advancing conservation actions in non-protected areas.
3. Basic empirical data needs to be collected on predation events. The location, size, sex and species of prey and predator are required. Along with this, the density of predators needs to be determined. There are limited density data available for African wild dogs, cheetahs and leopards in some areas to accurately determine livestock predation risk. Some livestock predation data may be available through permit offices, which should be analysed and published. A risk model of livestock predation by predators based on environmental and livestock management variables (or any other variables that can be identified), which allows for identification of high-risk zones to define mitigation strategies (e.g. Zarco-González, Monroy-Vilchi & Alaníz, 2013; Zingaro & Boitani, 2017) could be generated.
4. Basic biological and ecological knowledge (including movements, range, behaviour, prey availability) is needed for most species, especially outside protected areas, where they encounter people and livestock.

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PREDSA Glossary

These clarifications/definitions are provided to reflect their context in PredSA. For zoological aspects these are largely derived or extracted from BARROWS E.M. 2000. Animal Behavior Desk Reference: A Dictionary of Animal Behavior, Ecology, and Evolution, Second Edition. CRC Press.

Animal rights/liberation movement	A social movement that seeks change in the moral status and treatment accorded to animals. Sometimes this is grounded in the notion that animals have rights, just as humans do. The movement is characterised by a rejection of using animals instrumentally to promote human interests.
Animal welfarism	A social movement committed to reducing cruelty to animals and promoting their welfare. Animal welfarists are not opposed to the use of animals to fulfil human interests, so long as this is done in a way that minimises harm to the animals concerned.
Anthropocene	The most recent or current geological age which is notable for the impact that human activity has on the environment and climate.
Anthropocentrism	Anthropocentrism is the philosophical point of view that holds that only humans have a moral status. All other life forms are only of value instrumentally, in terms of their usefulness to humans.
Apex predator	A predator that sits at the top of a food chain. They are usually the largest predators in an ecosystem.
Bill	Proposed legislation under consideration by a legislature.
Bill of rights	A part of the national constitution which outlines the basic rights of every citizen.
Biocentrism	Biocentrism is an approach to ethics that extends moral status to all living entities. This is most often grounded in some notion of inherent value possessed by all living things.
Biodiversity	The diversity of life. Biodiversity can be viewed at multiple scales from the biochemical and genetic, through organisms to communities and landscapes.
Bottom-up limitation	The context where either a primary producer or a limiting nutrient(s) regulates an ecosystem's higher food-web components.
Case law	A collection of all judgments handed down at the end of all court cases. The principles and interpretations set out in case law can provide a basis for judgments in future, similar cases.
Civil law	The law relating to disputes between individuals.
Common Law	Laws that develop through case decisions by judges. Not enacted by legislative bodies.
Compensation	Money paid in recognition of work.

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Compensatory immigration	Populations experiencing different local mortality rates may display a source-sink system where individuals migrate from areas with lower mortality (source populations) to areas with higher mortality (sink populations), resulting in population recovery.
Compensatory reproduction	A population response to increased local mortality, where individuals increase reproductive output and compensate for increased mortality, resulting in population recovery.
Competition	An ecological concept describing the interactions between species where the interaction limits population growth of one or both species, usually but not exclusively in their need for shared limiting resources.
Complex decisions	Decisions which are made in the context of fundamental uncertainty.
Constitution	The supreme law of the land by which the country is governed. In the context of this assessment this refers to the "Constitution of the Republic of South Africa, 1996."
Criminal law	The law relating to order established by the State.
Customary law	Indigenous, legal practices developed over time through customs and tradition which are recognised by society.
Damage-causing predators	All predators that are known to kill livestock, irrespective of dietary preference.
Deontological	Pertaining to deontology. Deontology is the term used to describe a family of moral theories that ground morality in rules of conduct. These rules are often referred to as moral duties or obligations. Deontology is characterised by the rejection of the notion that it is the consequences of actions that determine their moral rightness or wrongness. This contrasts with Utilitarianism.
Ecological niche	The ecological niche of a species reflects how it fits into its biotic and abiotic environment and how the species in turn influences that environment.
Ecological or environmental impacts	The impacts that the application of a specific management intervention has on the target species/system and its ecology, and the environment, including non-target species/systems.
Ecosystem	An area of nature that includes living organisms and non-living substances that interact and produce an exchange of material between its living and non-living parts.

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Ecosystem services	Humans (and all other organisms) benefit from the natural environment in many ways. These benefits are commonly grouped into four main functional groups or services e.g. provisioning services such as raw materials for life; regulatory services such as decomposition of organic material; supporting services such as soil formation; and cultural services such as access to recreational opportunities.
Effectiveness	The degree to which a particular management intervention achieves its objectives.
Ethical methods	In the context of PredSA, management interventions that do not indiscriminately kill animals or inflict unnecessary suffering on the affected animal(s).
Facilitation	A species interaction where one species benefits and the other is unaffected. For example, apex predators provide scavenging opportunities for black-backed jackals, resulting in a positive effect of resource provisioning.
Facultative scavenger	An animal that primarily acquires its food resources through other means but which will on occasion scavenge for food.
Follower species strategy	In some ungulate species, a precocial neonate will follow its mother from birth onwards, remaining near her from an extremely young age.
Guild	A group of species that exploit the same class of environmental resources in a similar way.
Hider species strategy	In some ungulates species, an altricial neonate will remain hidden in dense vegetation until it is capable of keeping up with the mother.
Home range	The area in which an animal lives and moves in its general day to day activities.
Human-dimension of predation management	Stakeholder perceptions and views of predators and predation management, the driving factors behind these perceptions or views, and the resulting reactions of such stakeholders.
Immigration	Dispersal of individuals into a population.
Interspecific competition	Competition between individuals of different species for shared, limited resources.
Intraspecific competition	Competition between individuals of the same species for shared, limited resources.
Introgression	The flow of genes from one species to the genepool of another where an interspecies hybrid repeatedly “back breeds” with a parent from one of the populations.
Kraaling	The act of containing or corralling livestock, commonly executed at night to reduce the loss of animals to predation.

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Latrine	Areas where animals regularly urinate and defecate.
Lethality	In the context of PredSA, whether a management intervention kills the target predator, conspecifics or other species. However, the classification of some predation management methods as either lethal or non-lethal may vary depending on the context (see Chapter 6).
Mesopredator	Medium-sized predators. Actual size depends on the context but they are smaller than the apex (or top) predators for any particular ecosystem.
Mesopredator release	An increase in the number of smaller predators and shifts in their resource use that results from the removal of apex/larger predators in a particular area.
Metabolic scaling	A body of theory that relates the size of an organism to its metabolic rate and the ecological consequences of this relationship.
Moral status	Moral status (or moral standing) is used to distinguish between entities towards which we can have moral obligations. A being has moral status if an agent can owe it something morally. Moral status is often closely associated with the ability to have interests.
Natural justice	Principles of justice derived from an intuitive understanding of what is fair, e.g. that accused people must be told what the charges against them are, that they must be given a chance to defend themselves, etc.
Neonates	New born.
Niche	The multidimensional space that represents the total range of conditions within which a species can function and which it could occupy in the absence of competing species or other interacting species.
PredSA	The acronym used to identify this scientific assessment on Livestock predation in South Africa.
Primary consumers	Animals that feed on plants.
Productivity	The rate of accumulation of biomass in a species or in an ecosystem. This can be the increase in size of an individual organism or the number of organisms or both.
Regulated methods	In the context of PredSA, predation management interventions that are regulated by legislation in South Africa.
Resource partitioning	The situation where species reduce/avoid competitive interactions by using limiting resources in ways that reduce overlapping demands on the resource.
Sharecroppers	A tenant farmer who gives a part of each crop to the landowner as rent.
Sympatric	Populations or species whose geographical ranges overlap.

GLOSSARY

Territory	The space that individuals (often operating collectively as a social group) of a species defends.
Top-down regulation	An upper-level predator's regulation of an ecosystem's lower food-web species or processes.
Utilitarianism	Utilitarianism is a consequentialist moral theory, that claims that the morally right action is the one that will lead to an aggregated maximisation of good consequences for all affected by the action. It is only the consequences of actions that do the work of establishing what is morally right or wrong. Utilitarianism thus rejects the deontological notion that there are moral rules.
Vivisection	Vivisection literally means the performance of surgery on live beings for experimental purposes. However, the term has come to be used broadly to refer to all experiments using animal subjects, especially by those opposed to the practice.

Note: Taxa are listed by common names, followed by the scientific binomial.

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African fish eagle *Haliaeetus vocifer*

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African hare *Lepus capensis*

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environmental affairs

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Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA



CAPE WOOLS SA



Predators are valued as part of South Africa's natural heritage, but are also a source of human-wildlife conflict when they place livestock at risk. Managing this conflict ultimately falls to individual livestock farmers, but their actions need to be guided by policy and legislation where broader societal interests are at stake. The complexity of the issue together with differing societal perspectives and approaches to dealing with it, results in livestock predation management being challenging and potentially controversial.

Despite livestock predation having been a societal issue for millennia, and considerable recent research focussed on the matter, the information needed to guide evidence-based policy and legislation is scattered, often challenged and, to an unknown extent, incomplete. Recognising this, the South African Department of Environmental Affairs together with the Department of Agriculture, Forestry and Fisheries, and leading livestock industry role players, commissioned a scientific assessment on livestock predation management. The assessment followed a rigorous process and was overseen by an independent group to ensure fairness. Over 60 national and international experts contributed either by compiling the relevant information or reviewing these compilations. In addition an open stakeholder review process enabled interested parties to offer their insights into the outcomes. The findings of the scientific assessment are presented in this volume.

“Livestock Predation and its Management in South Africa” represents a global first in terms of undertaking a scientific assessment on this issue. The topics covered range from history to law and ethics to ecology. This book will thus be of interest to a broad range of readers, from the layperson managing livestock to those studying this form of human wildlife conflict. Principally, this book is aimed at helping agricultural and conservation policymakers and managers to arrive at improved approaches for reducing livestock predation, while at the same time contributing to the conservation of our natural predators.

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