Scientific Assessment on Livestock Predation in South Africa

CHAPTER 6

PAST AND CURRENT MANAGEMENT OF PREDATION ON LIVESTOCK

Lead author: J. du Plessis

Authors: N. Avenant, A. Botha, N. Mkhize, L. Muller, N. Mzileni, J. O'Riain, D. Parker, G. Potgieter, P. Richardson, S. Rode, N. Viljoen

Contributing author: M. Tafani

6.1. 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 *et al.* 2009; Barua *et al.* 2013). Instances of HPC may originate where predators prey on livestock (Wang & Macdonald 2006; Chaminuka *et al*. 2012), utilize resources of recreational value (Pederson *et al*. 1999; Skonhoft 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 and economic value (Engeman *et al*. 2002). In response, humans employ a range of management strategies to moderate the costs which they incur from HPC.

While many predation management strategies have shown some success in reducing livestock losses (Linnell *et al*. 2001), negative consequences of predation management have also been demonstrated, including: (1) the near extinction of predators in certain areas because of eradication programmes (Woodroffe & Ginsberg 1999; Treves & Karanth 2003; Bauer & Van der Merwe 2004; **Chapter 2**); (2) the alteration of ecosystems and apparent increases in the numbers of certain primary consumers and 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 *et al*. 2007; also see **Section 6.3**); (4) counterproductive predation management approaches, with more livestock losses occurring after their implementation (Allen 2014; Treves *et al.* 2016); and (5) the straining of relationships between livestock producers, different sectors of society and policy makers (Madden 2004; Thompson *et al*. 2013; **Chapter 5**).

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 resources are used for livestock farming (Meissner *et al.* 2013). However, the country is also a signatory to various global commitments to biodiversity conservation (**Chapter 4**). Thus, it is vital 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 internationally and consider their application in the South African context. We focus on the effectiveness of each method (see **Box 1**).

Box 1: Important technical terms and definitions used in this chapter.

Cost-effectiveness: The implementation and maintenance costs associated with a predation management method versus the value of the potential livestock losses that are prevented by the specific method (Davies-Mostert *et al*. 2007).

Damage-causing predators: All predators that are known to kill livestock, irrespective of dietary preference.

Duration of effectiveness: The length of time that a particular predation management method reduces livestock losses (i.e. short term ≈ weeks and months vs. long term ≈ years).

Ecological or environmental impacts: The impacts that the application of a specific method has on the target species and its ecology, and the environment including non-target species (Davies-Mostert *et al*. 2007).

Effectiveness: The degree to which a method reduces and/or prevents predation on livestock. However, for a more accurate description of effectiveness it is also important to consider cost-effectiveness and the environmental impacts.

Ethical methods: Methods that do not indiscriminately kill animals or inflict unnecessary suffering on the affected animal(s) (Davies-Mostert *et al*. 2007; Sharp & Saunders 2011; but also see **Chapter 5**).

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 (Miller 2009).

Lethality: Whether a method 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 **Section 6.3**).

Livestock: All domesticated animals (excluding poultry) and game (including ostrich *Struthio camelus*)

Predation management method: Method or strategy that is implemented to counter livestock predation or to manage a consequence of livestock predation (e.g. retaliatory killing of predators). Includes both preventative and reactive methods (see PMF 2016).

Regulated methods: Methods that are regulated by legislation in South Africa, including those that are subject to guidelines or norms and standards promulgated under any act or ordinance (Davies-Mostert *et al*. 2007).

Target-specific method: Method successfully targets only a specific species (≈ species specific) or individual (≈ individual specific).

6.2. Predation and predation management approaches used internationally

Wildlife 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 settings and scales of operation can also vary enormously. At a global level, three broad wildlife 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, the relative reliance on different strategies is 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.

Wildlife management in many parts of the world was originally used as a means to ensure continued hunting opportunities, particularly of large herbivores, 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 political pressure from animal welfare organisations and conservationists (Zinn *et al.* 1998). Simultaneously, non-lethal methods linked to preservation strategies have gained favour in some jurisdictions, despite the complexity and costs associated with their successful implementation. Wildlife managers are increasingly expected to balance the demands of protecting wildlife from people, and people and their livestock from predators (Treves & Naughton-Treves 2005; Treves *et al.* 2006; Redpath *et al.* 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 *et al.* 2017; Van Eeden *et al*. 2017).

The lack of appropriate case-control study designs, complex socio-political landscapes and historical idiosyncrasies have together promoted diverse responses to global wildlife 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 wildlife (e.g. population census, setting of hunting quotas) (Geist *et al.* 2001; Heffelfinger *et al*. 2013). This approach generates substantial income for local economies, promotes public interest in both consumptive and non-consumptive use of wildlife and, for the most part, has promoted stable wildlife populations while keeping livestock losses at apparently acceptable levels (but see Peebles *et al*. 2013; Teichman *et al*. 2016). Damage causing predators in the 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 *et al*. 2013). Importantly, Wildlife Services in the US also engages in applied research relevant to wildlife management and develops methods of particular relevance to for mitigating HPC (Bodenchuck *et al*. 2013).

The North American model is similar to that of Australia where the government owns and assumes responsibility for wildlife 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 *et al*. 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 fluroacetate) programmes and the 4600km Dingo Barrier Fence (DBF), that aims to exclude dingoes *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 evolved 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 wild dogs (McIlroy 1986; APVMA 2008). Additionally, bounties have been used throughout Australia to control pest species, and are continued 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, predator management in Europe initially focused on eradication, with bounties paid for predators killed with unselective trapping, shooting and poisons (Schwartz *et al*. 2003). However, unlike the US and Australia, countries in Europe do not have central authorities for managing damage causing animals with the resultant conflicts being largely managed on a case-by-case basis. More recently, there have been attempts to establish a framework for the reconciliation of human-wildlife conflicts, with many countries affording protected status to large predators in an effort to stimulate their recovery (Zimmerman *et al.* 2001; Chapron *et al*. 2013). 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 *et al*. 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 *et al*. 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 wildlife management. Hunting is 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*. 2015, 2016). 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 wildlife than commercial farmers or urban dwellers that purchase their food in supermarkets (Peterson *et al.* 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.

Unlike the North American, central African and Asian models for wildlife 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 devolution places the burden of managing damage causing animals on the individual, but also allows the profits of both consumptive and non-consumptive tourism 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; Natrass & Conradie 2015).

State-sponsored support for farmers in conflict with predators shifted to extensive fencing after World War II (Beinart 1998; Natrass & Conradie 2015) and was 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 (Natrass & 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 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 hunting clubs phased out and dedicated research 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 NGO’s 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 professional organisations (e.g. the Predator Management Forum), academic institutions and NGO’s for professional 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 been sold to so-called “weekend” or absentee farmers (Du Plessis 2013; Natrass & Conradie 2015). The result is that in many instances, predation management now occurs in isolation and on relatively small scales (≈ on a single farm or farm consortium).

In the absence of state-coordinated wildlife management and research, it is not surprising that management practices and policy are largely reliant on idiosyncratic and correlative research derived from adaptive management outcomes, mostly 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. As a consequence, there is intense contestation among increasingly diverse stakeholders on what works, where and why (Du Plessis 2013; Natrass & Conradie 2015). Some aspects of the debate are politically and inextricably linked to power relations as well as personal value systems (Raik *et al.* 2008). With a growing acceptance that ultimately wildlife management is people management (Manfredo *et al.* 2009; 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 (≈ human dimension of wildlife management - Miller 2009).

6.3. Predation management methods

Worldwide, humans have developed an array of techniques to respond to the impact (both perceived and real) of predation on livestock (**Table 1**). These techniques consist of both lethal and non-lethal methods and are generally either implemented as a precautionary (≈ preventative) measure to decrease the risk of livestock predation or as a remedial (≈ reactive) action after predation has occurred (PMF 2016). In South Africa, many livestock producers still attempt to lower predator numbers through unselective, lethal methods (Du Plessis 2013; McManus *et al*. 2015; Minnie *et al*. 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 *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). [**INSERT ADDENDUM PARAGRAPH**]

For the purpose of this chapter, we characterise the range of predation management techniques into the following seven groups: (1) disruptive deterrents (or primary repellents) which disrupt predator behaviour through a number of mechanisms such as neophobia, irritation, or pain (Shivik *et al.* 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 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; (5) non-lethal population control which aims to suppress 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 predators (either certain individuals or entire populations) (Dickman 2010).

6.3.1. Disruptive deterrents

6.3.1.1. 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 *et al.* 2015). It has been shown to successfully deter captive wolves and coyotes *Canis latrans* for short periods (≈ *ca.* 1 day) from areas where food is placed (Musiani & Visalberghi 2001; Mettler & Shivik 2006). 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 (in this instance 1-60 days). Furthermore, Mettler & Shivik (2006) found that fladry was less successful against dominant individuals that generally take more risks when it comes to livestock predation.

Table 1: Summary of the available predation management methods and their potential application in the South African context.

se strategy	Metho d	Description	Effectiveness[b]	Pros[c]	Cons[c]	Countries practiced/studie d[d]	Application for SA	Available information[e]		
								PR	SC	A
Disruptive deterrents/ Primary Repellents	Normal fladry	Flags or strips of plastic mounted on rope along top of fence	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
	Electrified fladry	Electrified poly-wire, with strips of plastic or flags mounted on the wire	Effective against wolves for up to 90 days	Rapid implementation; immediate success; 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
	Human herders	People range with livestock and may kraal/boma/corral at night	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 herdsmen 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 widespread farming areas with low densities of livestock; opportunity for job creation (e.g. Jobsfund; EPWP)	Y	Y	Y
	Guarding dogs	Specific dog breeds raised with the flock/herd; defend them against predators	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
	Other guarding animals	Donkeys; llamas; camels; alpacas	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
	Cellular technology	Collar sends a signal when abnormal behaviour is detected	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 or in extensive areas where stock cannot be reached quickly	Y	Y	Y
	Disruptive stimuli	Flickering lights and acoustic cues associated with human activity	Effective against a variety of species for short periods	Initial success; generally 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 us 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

[a] see **Section 6.3** for a description; [b] effectiveness of the method to decrease predation losses – see **Section 6.3** 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 **Section 6.3**; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see **Box 5**

Table 1 (cont.): Summary of the available predation management methods and their potential application in the South African context.

Response	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	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 as an addition to other techniques for shorter periods; may not work against all predator species; not recommended for more than two weeks	Y	Y	Y
Husbandry practices	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 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 enclosure	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 enclosure	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

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Table 1 (cont.): Summary of the available predation management methods and their potential application in the South African context.

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Husbandry practices	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
	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
	Altering herd composition (≈ flocks)	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
	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

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								PR	SC	A
Aversive Deterrents/Secondary Repellents	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	Predators smell and taste chemical and avoid eating; many aversive chemicals are carcinogenic; time consuming; expensive; difficult to catch all non-territorial animals; impractical to implement	UK; US	All farms, although it is unlikely to be effective and practical in South Africa	Y	N	Y
	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 as an addition to other techniques; certain predators may only take unnatural food (i.e. dog pellets) for short periods	Y	N	Y
Non-lethal population control	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
	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

Producer management	Compensation schemes	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 disincentive 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

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Response[a]	**Method**	**Description**	**Effectiveness**[b]	**Pros**[c]	**Cons**[c]	**Countries practiced/studied**[d]	**Application for SA**	**Available information**[e]		
								PR	**SC**	**A**
Producer management	Insurance programmes	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
Producer management	Financial incentives	Farmers are provided with incentives and business opportunities for mitigating HPC and reducing poaching; bounties are paid to kill certain species	Financial incentives motivate producers to implement or commit to certain predation management methods or to hunt 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 Afric	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
Lethal predator management	Shooting	High powered rifle used on target species, in combination with calling or from an aircraft	Moderate to high in the short term	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
Lethal predator management	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
Lethal predator management	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; Phillipines; 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	Meat or manufactured baits laced with poison	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 **Section 6.3** for a description; [b] effectiveness of the method to decrease predation losses – see **Section 6.3** 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 **Section 6.3**; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see **Box 5**

Table 1 (cont.): 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
Lethal predator management	Coyote getters/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 decrease livestock predation	More selective than baited poisoning; poison are more secured compared to baited poisoning	Traditional forms of getters are indiscriminate; capture bias towards 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

[a] see **Section 6.3** for a description; [b] effectiveness of the method to decrease predation losses – see **Section 6.3** 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 **Section 6.3**; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications and theses or dissertations, SC = semi-scientific publications, A = anecdotal – see **Box 5**

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 *et al*. (2010) found that under test conditions, electric fladry deterred wolves for longer (≈ 2 to 10 times longer) periods 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, National Wool Growers Association Consultant, Loxton, 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. 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 their successful implementation, especially on extensive livestock farms.

6.3.1.2. 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, University of Southern Queensland, Toowoomba, Australia, pers. comm.) and after the mid-1990's in the US (Hygenstrom *et al*. 1994), the method is still widely used in Africa and Europe (Kaczensky 1999; Ogada *et al.* 2003; Patterson *et al*. 2004). In the latter settings, livestock herds/flocks are generally kept in relatively small areas and are enclosed at night. Humans have also been successfully employed in various areas to deter primates from frequenting urban areas or to prevent crop raiding (e.g. Hoffman & O'Riain 2012). McAdoo & Glimp (2000) hypothesised that herders will likely be a successful predation management method in most cases because they can provide a reliable deterrent. An added advantage is that herders may be 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 *et al*. 2010; Hawkins 2012). 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 *et al*. 2017). Herders may also be less effective when flock or herd size increases, when flocks or herds are widely dispersed, and as grazing area (≈ farm or camp size) increases (Shivik 2004).

The latter issues could be less problematic when herders use working dogs to help guard their stock.

In South Africa, herders are successfully used by most subsistence farmers (Webb & Mamabolo 2004; Constant *et al*. 2015), presumably because these farmers 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 under such conditions. In addition, it is speculated that herders may not be cost-effective in the commercial context in South Africa because of high 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, unpublished data).

6.3.1.3. Guarding animals

A variety of animals have been used around the world to guard cattle, sheep, and goats from predators. The most well-known of these guardians are: dogs, donkeys *Equus asinus*, llamas *Lama glama*, and alpacas *Vicugna pacos* (Hygenstrom *et al*. 1994; Rigg 2001; Jenkins 2003; Weise *et al*. 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 applied successfully as guards (e.g. Coppinger & Coppinger 2001; Gonzáles *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 *et al.* 2010; van Bommel & Johnson 2012; Allen *et al*. 2016).

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 mesomales*, caracals *Caracal caracal*, cheetahs *Acinonyx jubatus*, leopards *Panthera pardus* and chacma baboons *Papio ursinus* (Marker *et al*. 2005; Horgan 2015; Potgieter *et al*. 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 occasionally 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 (≈ corralled) at night, and human herders are frequently employed to keep the livestock together (Potgieter *et al*. 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 *et al*. (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 compete with livestock for grazing. According to Potgieter *et al*. (2016), wildlife deaths caused by LGDs are, however, negligible. 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 & Schmidtz (1989) also reported some isolated 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. There is evidence confirming that LGDs can be effective under South African farming conditions. In a study by Leijenaar *et al*. (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 decreased predation on 43 small stock farms throughout 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) used in South Africa. 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 utilized correctly, alpacas, donkeys, and llamas can also be used successfully to 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 United States 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 & Feild 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, University of Southern Queensland, Toowoomba, Australia, 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 will 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 jennies 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 (Jenkins 2003; Weise *et al*. in Press) and aggression towards people (F. Weise, Claws Conservancy, Namibia, pers. comm.). These issues can be resolved or minimised by separating the guarding animal from the flock during lambing season, 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 available on the utilization of alternative guarding animals in South Africa. There has been an unconfirmed report of alpacas successfully deterring a troop of 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, which 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. 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).

6.3.1.4. Cellular technology

Cellular technology can be incorporated into an animal collar which sends a cellular signal to the farmer when abnormal behaviour (e.g. running) is detected within a livestock herd (Lotter 2006; Viljoen 2015; PMF 2016). The farmer can then investigate and respond accordingly. A disadvantage of cellular technology, however, is the lack of cellular reception in many of the farming areas in South Africa. Using satellite or GPS transmission could overcome the issue of poor reception, but the potentially high cost of GPS/satellite collars will likely prohibit their use. Cellular 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 running for reasons other than predators may reduce farmer response rates to actual predation events.

6.3.1.5. Disruptive stimuli

Disruptive stimuli are applied through devices (≈ frightening devices) that generate noises, lights, reflections or smells (Pfeifer & Goos 1982; Bomford & O'Brien 1990; Hygenstrom *et al*. 1994; Shivik & Martin 2000; Shivik *et al*. 2003; VerCauteren *et al*. 2003). Bell collars are primarily applied as a disruptive stimulus, although they may also act as a protection collar (see **Section 6.4.1.6**). Breck *et al.* (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 *et al.* (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.

Despite these apparent successes, it has been noted that the effectiveness of the various disruptive devices might be short-lived because carnivores habituate rapidly to them (Smith *et al*. 2000, Shivik *et al*. 2003). Various studies which have tested the use of different disruptive devices to deter primates have also 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 *et al.* 1990) or developing deterrents according to the target species' biology, i.e. using a predator model or playing back target species' distress calls (Belant *et al*. 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 for some devices (Gilsdorf *et al*. 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 experimentally. Because of habituation, it is likely that disruptive devices will only be effective in the short-term (but see **Box 2**).

Box 2: 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 conducted 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 (Tafani & 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 *et al*. 1998; Hill & Wallace 2012; McGuinness & Taylor 2014; Richardson *et al*. 2016) and Saudi Arabia (Biquand *et al*. 1994). Management strategies are generally tailored to local problems and seldom achieve long-term success because baboons readily habituate to deterrents and overcome 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 *et al.* 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, have kept baboons out of the urban areas of Cape Town for

over 98.5% of the time (Richardson *et al.* 2016). Baboons are able to learn raiding (Strum 2010; Richardson *et al.* 2016) 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 (Laundré *et al*. 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, Cromsight *et al*. 2013). Furthermore, behavioural responses should vary depending on how the level of risk varies in time and space (Cromsight *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) (Cromsight *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 2014). Baboons are therefore ideally suited to management by virtual fencing. In view of this, a 2km 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 *et al*. 2014).

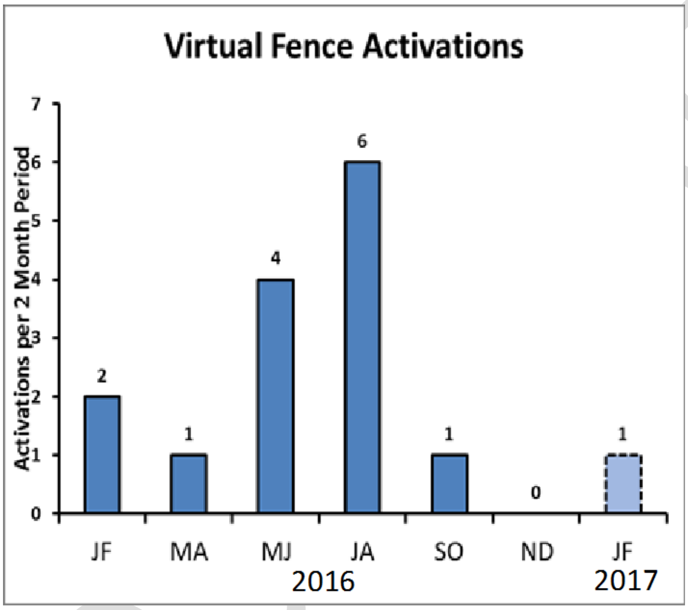

Figure 1. Number of virtual fence activations per two month period from January & February 2016 – January & February 2017. Dotted line indicates activation for a solitary male in January 2017 (from Richardson *et al.* 2017).

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 500m of the virtual fence, then a team of rangers was sent out to observe from a distance, and unobtrusively deploy the action stations if the baboons were continuing to approach. Five action stations were placed about 75m apart and out of sight, but directly in the path of the baboons. If the troop advanced to within 50 – 70m 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 1**; 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.

Virtual fencing is an innovative, new tool that has several management benefits over traditional barrier fences (Jachowski 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 utilized 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.

6.3.1.6. Protection collars

Protection collars consist of a plastic or metal collar that protects 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 **Sections 6.4.1.5 and 6.4.7.2**). There is a general lack of scientific evidence on the effectiveness of protection collars to deter livestock predation. However, Steinset *et al.* (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 for throat bites (Conover 2002). In South Africa, questionnaire studies show that livestock farmers often indicate that they use protection collars (Van Niekerk 2010; Badenhorst 2014). However, it is also often alleged that certain South African predators, especially black-backed jackals, get habituated to protection collars and attack the hindquarters when they are unable to inflict a throat bite (Todd *et al.* 2009).

6.3.2. Husbandry practices

6.3.2.1. 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 (≈ Dingo Barrier Fence) to keep the dingo from small-stock producing areas (Newsome *et al*. 2001; Allen & Fleming 2004; Clark *et al*. in Press.). Currently, fencing is one of the most preferred non-lethal predation management methods on livestock farms throughout South Africa (Van Niekerk 2010; Badenhorst 2014; Schepers 2016). South African farmers either use it to enclose their entire property, certain areas of their farms (e.g. habitats that are believed to be frequented by predators), or smaller camps for breeding 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) is effective at excluding most canids (most notably black-backed jackals – Davies-Mostert *et al*. 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; Smuts 2008; 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) & Perkins (2013), in studies conducted 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 on an on-going basis 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 subterranean and fossorial species (e.g. aardvark *Orycteropus afer* and porcupine *Hystrix africeaustralis*) 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 semipermeable fences (i.e. fences with specially designed gaps installed at intervals) that can allow digging species through and still exclude predators (Schumann *et al.* 2006; Weise *et al.* 2011). However, it is possible that predators may habituate to these fences in the long term (Niel Viljoen, National Wool Growers Association Consultant, Loxton, pers. comm.). Fences may also have negative ecological impacts by fragmenting the landscape and preventing dispersal of non-target wildlife that perform important ecological roles. For example, in Australia, predators were excluded from large parts of the country by the famous Dingo Barrier Fence (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 (≈ 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 demonstrated in any Australian or African ecosystem (Allen *et al*. 2013a; Allen *et al.* 2017).

6.3.2.2. Night/Seasonal enclosures

Night enclosures (≈ kraals/corrals/bomas) are used to protect livestock at night and seasonal enclosures (≈ shed-lambing or "lambing-camps") are employed to protect vulnerable livestock during the early parts of the lambing or calving season (Knowlton *et al.* 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 effective at limiting predation from a variety of carnivore species (Robel *et al*. 1981). Kraals have been and are still widely used by subsistence farmers to successfully protect their stock at night (Ogada *et al.* 2003), including in South Africa (Webb & Mamabolo 2004; Constant *et al*. 2015). 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. The technique is an intensive practice which may have 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 (because diseases may be more easily transferred 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 expensive 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.

6.3.2.3. 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 *et al*. (2015) reported that the majority of livestock farmers bordering the Baviaanskloof Mega-Reserve, Eastern Cape province indicated that they regularly 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).

6.3.2.4. Timing of breeding

Livestock predation often peaks during the lambing or calving seasons (see **Chapters 7 and 9**) or during drier periods when natural food is limited (Tafani & 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 (Hygenstrom *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 interaction between males and females. Some livestock producers in South Africa do use this method and indicate that it effectively decreases their livestock predation (Van Niekerk 2010; PMF 2016), but limited data means that it remains to be subjected to formal scientific assessment. Importantly, as the lambing season is generally the time when most small stock are lost (e.g. Avenant & Nel 2002; Morwe 2013; 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 nutritional or productivity costs, which may not be desirable.

6.3.2.5. Altering herd composition

The implementation of flerds (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 *et al*. 1987; Anderson 1998). However, McAdoo & Glimp (2000) and Shivik (2004) highlighted various shortcomings with this approach. It can be a very time-consuming and strenuous process, especially when trying to bond different livestock species. In addition, in some areas it could 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 and continue to attack (McAdoo & Glimp 2000; Shivik 2004). It is sometimes possible to switch to certain livestock breeds that are less susceptible to predation (Greentree *et al.* 2000, White *et al.* 2000). However, such switching may not always be economically or environmentally viable (Du Plessis 2013).

6.3.2.6. 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; Hygenstrom *et al*. 1994). Presumably this is because the removal of potential food resources (≈ 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 predate 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 considered scavengers (see **Chapters 7 and 9**).

6.3.2.7. Grazing and natural prey management

Rodents and small game comprise the bulk of the diets of most livestock predators in South Africa (see **Chapters 7 and 9**), and similar results have been found in Australia (Allen & Leung 2014). It has been suggested that if these natural food sources are preserved on farms, livestock predation could be reduced (Avenant & Du Plessis 2008; Du Plessis 2013; PMF 2016). It has also been suggested that through proper grazing management, by reducing herd sizes 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; PMF 2016). It is expected that a proper grazing management strategy will also enable livestock to reach optimum growth and condition 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 reproduction or lactation, and that some individuals may even "learn" to specialize on livestock (Avenant & Du Plessis 2008; Fleming *et al*. 2012; Du Plessis *et al.* 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.

6.3.3. Aversive deterrents

6.3.3.1. 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 which are placed in specific baits under field conditions, 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). The majority of the available studies have, however, found the method to be ineffective (Burns & Connolly 1980; Conover & Kessler 1994; Hansen *et al*. 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.

6.3.3.2. 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 *et al*. 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 *et al.* 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 these situations. In addition, the National Society for the Prevention of Cruelty to Animals (NSPCA) in South Africa has made it clear that they do not support the use of shock collars on wildlife as they consider them to be potentially cruel. Despite this, they do support the use of paintball markers and bearbangers to manage wildlife under direct observation (P. Richardson, Human Wildlife Solutions, Cape Town, pers. comm.).

6.3.3.3. Electric fencing

The electrification of existing fences may increase their effectiveness at excluding damage-causing predators, because the predators will not risk being shocked (McKillop & Sibly 1988; Hygenstrom *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, US, black bears *Ursus americanus* success 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 *et al*. 1997; Yelland 2001), and to protect threatened fauna from dingoes and other predators (Long & Robley 2004). In South Africa, a study by 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 *et al.* (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 the correct planning and design (Todd *et al*. 2009).

6.3.4. Provisioning

6.4.4.1. Supplemental feeding

Although supplemental feeding has been used successfully in the Cape Peninsula, Western Cape to temporarily distract chacma baboons from raiding urban areas (Kaplan *et al*. 2011), it has not yet been tested in the livestock predation context. A major concern is that supplemental feeding could increase the fecundity of predators and the territorial behaviour and/or social structure 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).

6.3.5. Non-lethal population control

6.3.5.1. Translocation

Translocation has been used to re-locate predators to areas away from the existing conflict. A review by Linnell *et al*. (1997) and a study by Weilenmann *et al*. (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 conservation groups in South Africa that are actively involved in “rescuing” and translocating apparently problem predators (e.g. CapeNature 2017; Landmark Foundation 2017). Monitoring the outcomes of these translocation operations may provide a good opportunity to gather valuable scientific data on the method. Nevertheless, 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).

6.3.5.2. 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) also 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 that must be considered. 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 a time consuming and costly technique. 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 a sex within a target population (Mitchell *et al*. 2004; Shivik 2004; Connor *et al*. 2008). Significantly, there are no species-specific contraceptives available which could be applied to baits and left in the field due to the possible impact 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 an application outside of small, isolated areas.

6.3.6. Producer management

6.3.6.1. Compensation schemes

Compensation is generally implemented to reduce the persecution of less common or protected species that kill livestock (Bulte & Rondeau 2005; Rajaratnam *et al.* 2016). Although there are examples of compensation schemes that have successfully decreased the retaliatory killing of predators (Bauer *et al*. 2015), Bulte & Rondeau (2005) and Rajaratnam *et al.* (2016) highlighted a number of significant shortcomings associated with compensation schemes. When compensation schemes are available, producers may stop putting sufficient effort into 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. People may be discouraged from claiming compensation because of the time and cost involved in the process (Bulte & Rondeau 2005; Rajaratnam *et al.* 2016). In general, if compensation schemes are well administered 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 and 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).

6.3.6.2. Insurance programmes

Insurance programmes rely on livestock owners paying a premium on a fixed basis that enables the contributor to get refunded in the event of losses due to livestock predation (Madhusudan 2003). Although insurance programmes can be implemented successfully for subsistence farmers where livestock 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, particular 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).

6.3.6.3. Financial incentives

Bounties are generally used as a measure to control invasive or “problem-causing” species. People are paid for every individual hunted 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 *et al*. 2005; Proulx & Rodtka 2015). Furthermore, as highlighted by the current chapter, various environmental and ethical concerns could also arise where bounties are used to reduce predator numbers.

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 3**). 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 *et al.* 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 3: 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 (also see **Chapter 4**). 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 *et al.*

(2002), Kleiven *et al*. (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 *et al*. (2007) and Bath *et al*. (2008) found that people showed more dislike for specific species once they were instructed on how to manage these species.

6.3.7. Lethal predator management

6.3.7.1. 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 on sight or through concerted culling operations (Hygenstrom *et al*. 1994; Mason 2001). Secondly, shooting is used to eliminate damage-causing individuals in a specific area after a livestock predation event (Hygenstrom *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). Currently, shooting is the most frequently used predation management method across all types of livestock farms in South Africa (Van Niekerk 2010; Badenhorst 2014; Schepers 2016). 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 foetuses (also see Loveridge *et al*. 2007; **Chapter 7**).

However, in the US, Wagner & Conover (1999) maintained that aerial gunning (≈ 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. 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, National Museum, Bloemfontein, 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 *et al*. 1999). Calling has also been noted to successfully attract breeding coyotes (≈ 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 (Niel Viljoen, National Wool Growers Association Consultant, Loxton, pers. comm.).

6.3.7.2. 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 (Hygenstrom *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 (≈ 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).

6.3.7.3. 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). However, it is currently illegal in South Africa for dogs to capture a predator although they can still be used to chase or point (≈ dogs search for the target and bark when they find it) 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.

6.3.7.4. Poisons

Poisoned baits are considered a highly unselective method 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, Karoo Predator Project, University of Cape Town, Cape Town, 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 *et al*. 2002; Thomson & Algar 2002; Burrows *et al.* 2003; Allen *et al*. 2013b). However, Gentle *et al.* (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. For example, the Wildlife Poisoning Database of the Endangered Wildlife Trust lists 174 individual incidents of poisoning of non-target raptor species in South Africa resulting in 2023 mortalities (A. Botha, Endangered Wildlife Trust, Johannesburg, pers. comm.).

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 (≈ 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 of 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 *et al.* (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) 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 *et al*. 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 *et al*. (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 the livestock (Burns & Connolly 1995), and scavengers can be affected when they eat predator carcasses (Burns *et al*. 1991; Snow 2008), although this can be prevented to an extent by using certain poisons and specific dosages. In South Africa, Avenant *et al*. (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 monofluoroacetate (≈ Compound 1080) can be used (NEMBA 2004).

6.3.7.5 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 or snares. 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.

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 used effectively 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 Endangered Wildlife Trust, 50% of the 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 captured a large percentage of 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, National Wool Growers Association Consultant, Loxton, pers. comm.). Indeed, Kamler *et al*. (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 (≈ soft traps) are permitted in South Africa (NEMBA 2004).

Three types of snares exist, namely body-, neck-, or foot-snares (Gese 2003; Turnbull *et al.* 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 types of 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 *et al*. 1999; Gese 2003). Because of their relative simplicity, low cost and because they are easy to handle, 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 *et al*. 2003; Turnbull *et al.* 2011).

6.4. Integration of methods within an adaptive management framework

Section 6.3 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; Ekland *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 4**). Reasons for this perspective include the following insights:

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; **Chapters 7 and 9**).
2. Confounding variables: Particular combinations of methods may be counterproductive (Hygnstrom *et al*. 1994; N. Avenant, National Museum, Bloemfontein, pers. comm.; N. Viljoen, National Wool Growers Association Consultant, Loxton, 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 evade the area/camp/part of the camp where the LGD is present (≈ 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. <u>Habituation</u>: Given the learning capacity of mammals in general and social carnivores in particular, the overuse and misuse of specific methods may greatly increase the rate at which predators habituate to them (see **Section 6.3**). 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 (≈ management of the natural prey base), livestock management practices (≈ lambing in designated camps; regular and continuous flock monitoring and moving; removal of carcasses), preventative non-lethal predator management methods (≈ bells, protection collars) and selective lethal predator management methods (≈ 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 4: Adaptive management recommended to farmers in the absence of a clear, scientifically informed management strategy.

In the early 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; S. Hanekom, Former CPA

Problem Animal Hunter, pers. comm.). 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 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 6.4**) 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 a direct (≈ predator displaced to their farm) or indirect (≈ 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.

6.5. Conclusions

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 on their overall efficacy internationally (see Treves *et al.* 2016; Eklund *et al*. 2017), and the fact that virtually nothing has been done in the South African context, which makes it almost impossible to scientifically accept or refute any specific method. This is not to say that these predator 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).

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 (≈ 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 welfare and biodiversity concerns amongst stakeholders (see **Chapter 5**);
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 predator 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 in order to protect his/her animals (see **Box 4**). 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 (also see Treves *et al.* 2016; Eklund *et al*. 2017; van Eeden *et al*. 2017). 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 5: Understanding the scientific value of different information sources.

> A relatively large pool of publications on predation management is available to draw information from (this chapter). 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 (National Research Council 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 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 with which many of the experiments culminating in scientific publications are performed, which preclude 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 (≈ 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 (National Research Council 2004).

6.6. Research questions

Based on our assessment, it is clear that 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). Considering this overall lack of information, it is necessary to prioritize research on specific management methods (e.g. target specific methods, non-lethal methods, or ethically acceptable methods). It is important that this research is of an appropriate scientific standard (i.e. randomised with repeats and controls - see 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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