Scientific Assessment on Livestock Predation in South Africa

CHAPTER 3

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

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Introduction

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

The management of predators on private rangelands in South Africa has changed dramatically over time. Changes in management practices have been driven by changes in technology as well as changes in scientific understanding and public sentiment. Boreholes were introduced around the turn of the 20th century, which enabled commercial livestock farmers to change from a kraal system to one where sheep were kept in camps. Government introduced programmes to facilitate jackal-proof fencing and the extermination of predators from camps (Nattrass *et al.* 2017). Predator removal was achieved through a bounty-hunting system that persisted until the 1950s, and then by district hunting clubs that employed professional hunters, supplied hunting dog packs and trained farmers in trapping and poisoning. These state-supported measures led to high rates of culling of a number of species including non-predatory species that competed for grazing such as dassies *Procavia capensis*. With this support, farmers were able to employ 'fence and clean-up' methods to great effect (Nattrass & Conradie 2015, Nattrass *et al.* 2017). Problems were reportedly greatly diminished between the 1920s and the 1960s, but caracals *Caracal caracal* and later black-backed jackals *Canis mesomelas* started to increase again thereafter. Government support of the agricultural sector started to diminish in the late 1980s and along with it, public assistance for the control of predators. This effectively put the situation back in the hands of the farmers, who complained of a resurgence of predators on their lands (Nattrass & Conradie 2015). At the same time, increasing awareness and concern about animal welfare, endangered species and effectiveness of certain methods led to greater restrictions on the species that could be culled as well as the methods of control, which meant that the way in which farmers could deal with problem animals became restricted. Meanwhile, new legislation and the opening up of South Africa to international tourism also encouraged the proliferation of game farming from the early 1990s, which markedly changed the nature of the landscape and which has also been blamed for contributing to increases in problem animals. Therefore, by all accounts, today's commercial farmers are faced with a very different situation than at any previous time. Their current situation has been fairly well documented in a series of recent studies of small-stock, large-stock and game farmers throughout South Africa.

Communal areas have never had the same level of support as the commercial farmers, and the problem in these areas has received considerably less attention. There is relatively little information on the effect of predation and on farmer responses in these areas in South Africa, though much more is known from comparable areas in other parts of the southern Africa.

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

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

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

Overview of the livestock and wildlife farming sectors

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

Livestock carrying capacity increases from west to east with increasing rainfall (Figure 1). Sheep are the main stock in the drier western and central areas, while cattle tend to dominate in the wetter eastern rangelands. However, many rangeland areas are stocked beyond their long-term carrying capacity, particularly in the communal rangelands of Limpopo, KwaZulu-Natal and the Eastern Cape. These small scale/communal farming areas support more than half of South Africa's cattle (Meissner *et al.* 2013) and are important for rural livelihoods, but they contribute comparatively little to marketed production.

Game farming occurs throughout, but is more prevalent in the more mesic eastern and northern areas.

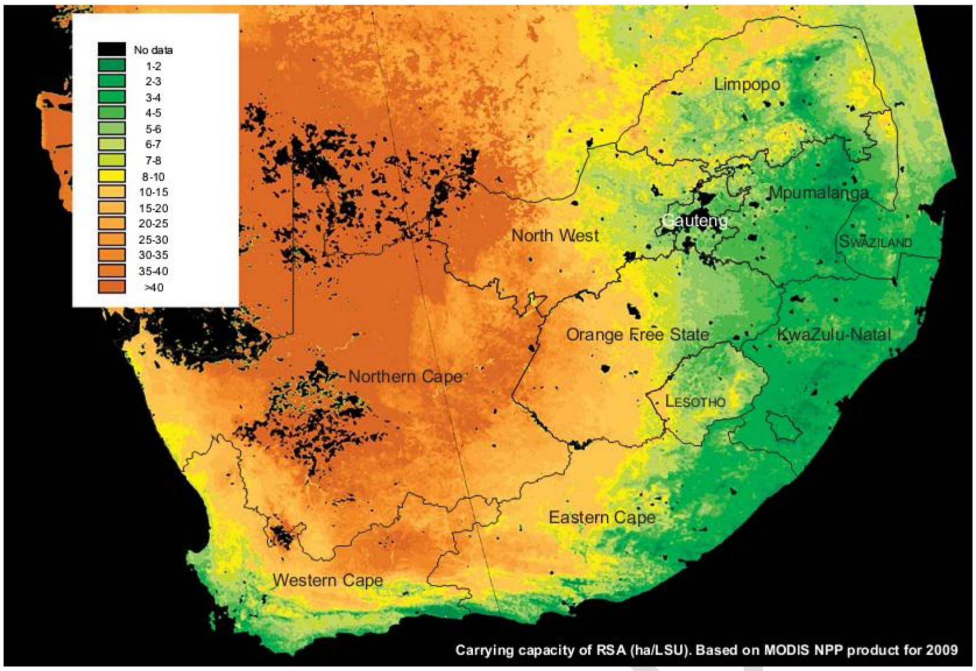

Figure 1. Livestock grazing capacity (ha/LSU). Source: Meissner 2013.

As of 2010, South Africa had an estimated 13.6 million beef cattle, 1.4 million dairy cattle, 24.6 million sheep, 7 million goats, 3 million farmed game animals, 1.1 million pigs and 1.6 million ostriches in addition to poultry (Meissner *et al.* 2013; Figure 2). These are raised on about 38 500 commercial farms and intensive units and by some two million small-scale/communal farmers (Meissner *et al.* 2013).

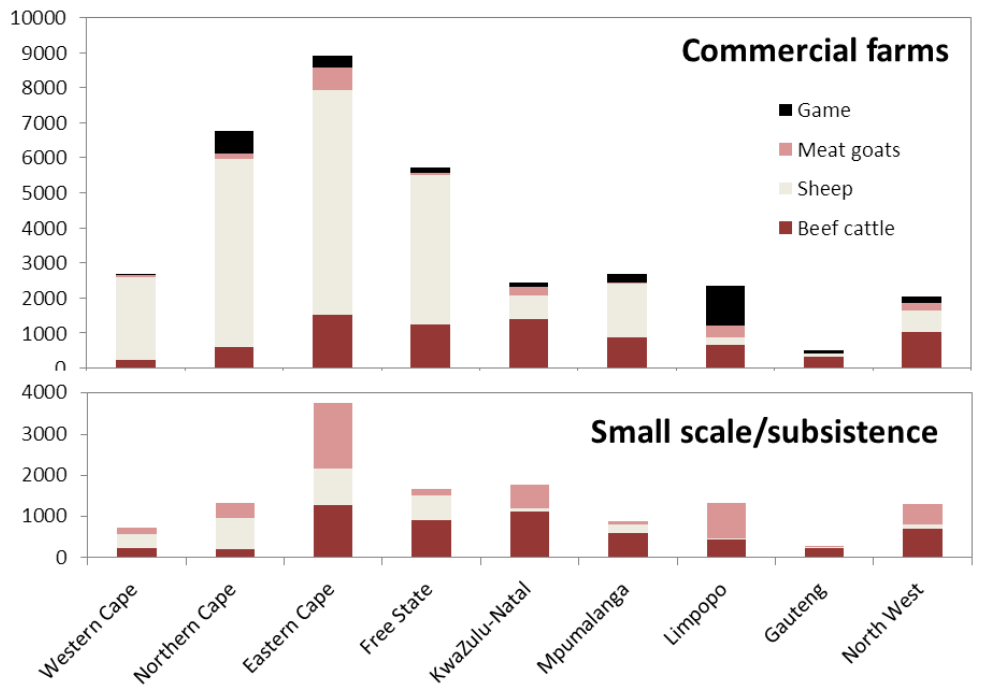

Figure 2. Estimated cattle, sheep, goat and game numbers in South Africa (2010) (in thousands). This excludes 21 000 dairy goats and 1 million Angora goats. Source: Meissner et al. (2013).

Sheep and goats are farmed extensively, particularly in the drier regions of the country. These include mutton sheep, particularly the Dorper, which is adapted to harsh conditions, and wool sheep, mainly Merinos. Overall numbers of sheep have decreased to 68% of their numbers in 1980 (DAFF, 2016), and the proportion of Merinos has also declined, from 65% to 52% of total sheep. Goat numbers have diminished to 72% of their numbers in 1980. Commercially-farmed goats are dominated by Angoras and Boer goats, with indigenous goats being farmed in the emerging/communal sector. Ostriches are also important in some areas.

Declines in sheep numbers are a worldwide trend (Morris 2009), and relate to decreasing prices of products such as wool, as well as increased input prices, reduced subsidies and labour market reforms. However, it is important to note that small ruminants are relatively resilient to higher temperatures, and their importance may increase again under future climate change conditions (Rust & Rust 2013). Globally, the sheep farming industry had undergone major efforts to improve productivity and profitability, for example through adaptive management. In New Zealand reproductive efficiency improved from a lambing percentage of less than 100% in the late 1980s to 125% by 2008 (Morris 2009). However, there was little technical progress in South Africa's sheep farming districts during 1952 to 2002 (Conradie et al. 2009) while in the rest of agriculture there was technical progress of 1-1.5% per year over a similar period (Thirtle et al. 1993). Furthermore, past attempts to accelerate technical progress in sheep farming areas (Archer 2000) might have led to over exploitation (Dean et al. 1995, Archer 2004, Conradie et al. 2013). Thus the small stock sector is particularly vulnerable and is in urgent need of innovation in the areas of genetics and breeding, nutrition and research on pasture management, strategies to improve reproductive efficiency and deal with labour constraints. Strategies to improve prices such as the Karoo Lamb certification initiative are also very important.

In contrast to small stock, the national cattle herd increased since the 1970s along with increasing domestic demand for beef (Palmer & Ainslie 2006), but has remained fairly stable since 1980 (DAFF 2016). These cattle are not entirely supported by rangelands, as 75% of South Africa's cattle spend a third of their lives in feedlots (WWF undated).

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

Meanwhile, the numbers of farmers and farm workers have decreased markedly over time. Largely as a result of farm consolidation, there has been a 31% decline in the number of farmers since 1993, and the number of farms (including crop farms) has decreased by 40 000 (WWF undated). Small and marginal farmers that had been reliant on subsidies and soft funding from institutions such as the Land Bank started to suffer as support was withdrawn, markets opened up and competition increased. These farms were bought out, farms were consolidated and farming net incomes grew considerably as a result of economies of scale (WWF undated). The decrease in agricultural labour is likely to have resulted from both the consolidation of farms and the development of stricter labour laws (Turpie *et al.* 2003). These changes are particularly relevant in the broader socio-economic context in which South Africa finds itself in the 21st century. Declines in income and employment in the livestock sectors and associated declines in the economies of small towns have probably contributed to the high levels of poverty and inequality in the country. The challenges faced in these areas also have an important bearing on land reform and the establishment of emerging black farmers.

The nature of livestock depredation

Livestock predation in South Africa is predominantly by the black-backed jackal and caracal which are common throughout. In the main small-stock farming areas, these account for over 65% and 30% of predation losses overall (Van Niekerk 2010). Large predators such as lions *Panthera leo,* African wild dogs *Lycaon pictu*, and spotted hyaena *Crocuta crocuta* occasionally occur on private lands in the northern and eastern parts of the country, but are only resident inside protected areas and private reserves with predator-proof fencing (Thorn *et al.* 2013). Other mammal species that take livestock include leopard *Panthera pardus*, cheetah *Acinonyx jubatus*, brown hyaena *Hyaena brunnea*, dogs *Canis familiaris* and baboons *Papio ursinus*. Leopards, cheetahs and brown hyaenas are mostly found outside protected areas (Marnewick *et al.* 2007; Mills and Hofer 1998) and are threatened by persecution in farmlands (Friedmann and Daly 2004). Leopards now tend to be largely confined to mountainous terrain. Baboons occur throughout, but do not commonly kill livestock. Domestic dogs can be a significant problem, however, particularly near towns (Davies 1999, Thorn *et al.* 2013).

Black-backed jackal and caracal account for most predation on small stock throughout the main farming provinces (Figure 3; van Niekerk 2010). Jackal are also the main predator on cattle farms throughout all cattle provinces apart from Limpopo (Figure 3; Badenhorst 2014). While caracal are also the second most important predator of cattle, a number of other predators play an important role, notably leopard, which was the most important predator in Limpopo province, and brown hyaena. Studies of unselected farm types in Limpopo and North West which both had a high proportion of game farmers showed that jackal, caracal and leopard were the main predators, with leopard being the most important in North West (Figure 3; Thorn *et al.* 2012, 2013).

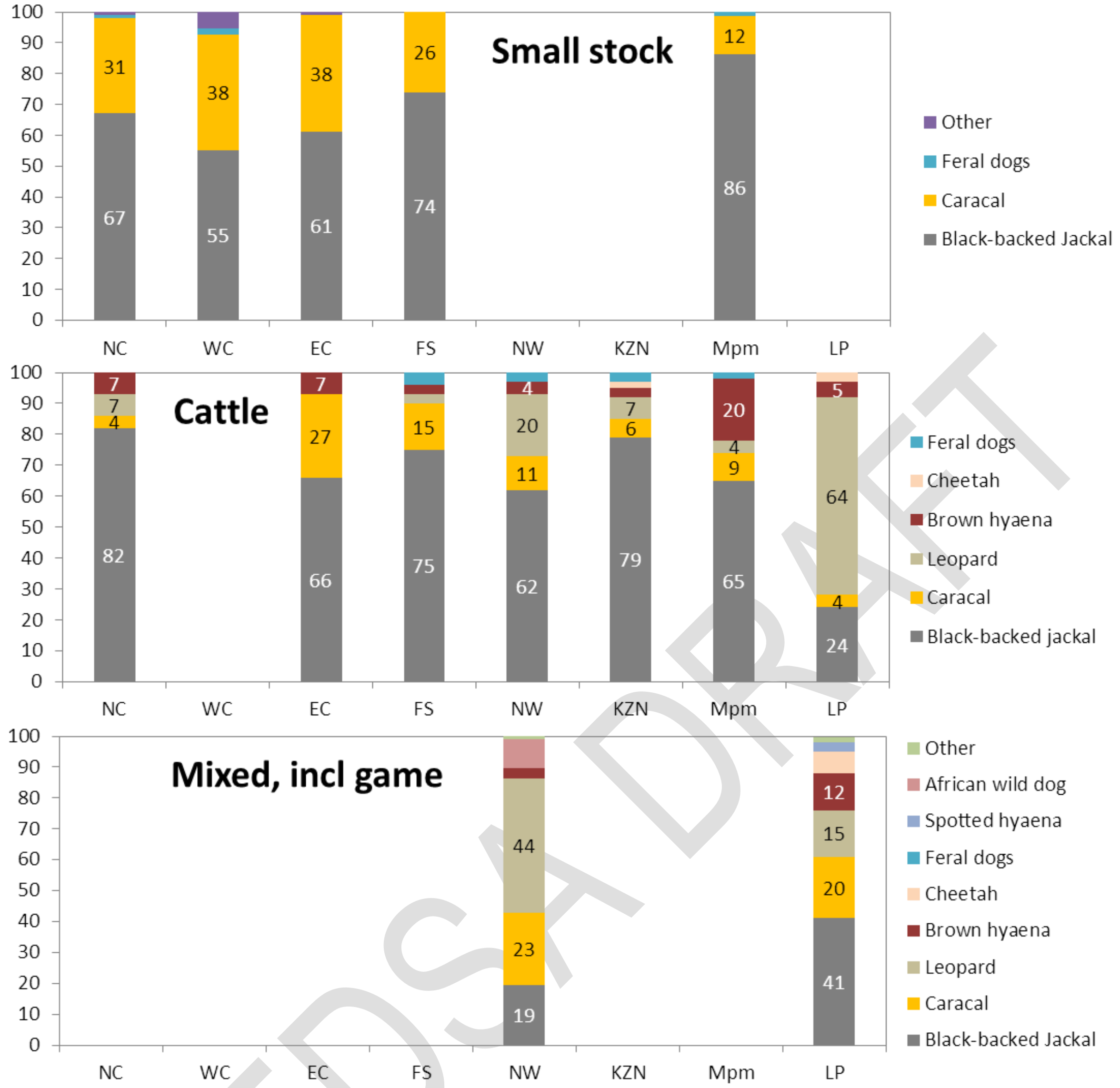

Figure 3. Relative extent of predation on commercial farms by different predator species in the provinces in which farmers were surveyed. Sources: Small stock farms – van Niekerk (2010); cattle farms – Badenhorst (2014); all types of farms - Thorn et al. (2012, 2013).

It is interesting to note that eagles were not mentioned in any of these studies. The larger eagle species such as Martial Eagle *Polemaetus bellicosus*, Verreaux's Eagle *Aquila verreauxii* and Crowned Eagles *Stephanoaetus coronatus* are quite capable of killing small livestock, and can take sheep up to half of adult size. Because of this, large numbers of Black and Martial Eagles were hunted in the Karoo in the 1960s (Siegfried 1963). Livestock do not form a major part of their diets, however. Studies of prey remains in the Karoo have shown that sheep comprise less than 2% of Black Eagle diets, and that a Black Eagle pair consumed about 3 lambs per year on Karoo farmland (Davies 1999). These predation events were too rare to be picked up in observations. However, in denser vegetation of the Eastern Cape, lambs have been found to comprise 8% of prey remains of Black Eagles (Boshoff *et al.* 1991 in Davies 1999). Farmers give highly variable accounts of losses to eagles: Davies (1999) reported that half of 37 farmers interviewed reported no lamb losses to eagles, 2 7% reported occasional losses and 24% reported significant losses. It is likely that whereas most eagles do not actively hunt livestock, a few pairs may take to doing so. The cost of having eagles on a farm is probably negligible (Davies 1999). Based on necroscopy studies, Davies (1999) found that eagles were responsible for only 1% of kills in South Africa, whereas their role was far more significant in other countries, especially the UK (16% of kills).

With most of the predators being relatively small, it is generally reported that livestock depredation is almost entirely of very young animals. In a study of small-stock farmers across the country, van Niekerk (2010) found that the majority of losses were of animals less than one month old. De Waal (2007) also reported predation on sheep farms to be mainly of young lambs before weaning, and Viljoen (2016) reports that 89% of all predation mortalities of wool sheep occur before weaning age. In the North West, 57% of farmers (all types) claimed that most of the game and livestock animals preyed upon were <12 months old, with game animals predated being species with adult female body weight between 23 and 70 kg (Thorn *et al.* 2013). Goats and sheep were the preferred livestock and cattle were less affected (Thorn *et al.* 2013). It is important to note that predation losses can be reported in various ways, e.g. relative to the numbers of lambs born, breeding ewes or total stock or for limited age categories (e.g. lambs only). In this assessment we have attempted to collate data on total losses as a proportion of total stocks as far as possible, but deviations from this are made clear where appropriate.

The extent of livestock depredation

Private rangelands

While livestock depredation has always been a concern for farmers in South Africa (Beinart 1998), there have been very few quantitative estimates of the problem until relatively recently. Early studies have been criticised as being overestimates. In some cases, this was thought to be due to exaggeration of the problem by farmers (Nesse *et al.* 1976, Armentrout 1980, Boshoff 1980, Hewson 1981 in Davies 1999), or their tendency to ascribe unknown causes of losses to predation. In other cases, this is due to sampling bias. For example, Brand (1993) calculated that losses from black-backed jackal ranged from 3.9% to

18%, but these estimates were probably biased towards high predation areas and farmers that encountered losses (van Niekerk 2010). In a 19-month study of 8 farms, Rowe-Rowe (1975) estimated that jackals resulted in annual losses of only 0.05% of the total sheep population in KwaZulu-Natal.

It can be difficult to assess the quality of farmer responses in studies of predator losses. Not all losses are actually observed, as some animals go missing. Some lambs may be scavenged after death, and usually only parts of carcasses are found, so that cause of death is uncertain (Strauss 2009). Also, determining the type of predator responsible may not always be easy, and kills by less common predators might be wrongly assigned. Farmers may also bias their responses for strategic reasons. A more reliable way to determine the causes of livestock deaths is through necroscopy studies undertaken by independent observers. Based on data from a number of such studies collated from sheep farms around the world, Davies (1999) found that predators were responsible for a much lower proportion of losses than is typically reported (Table 1). The estimated predation loss for South Africa (1%) was much lower than previous and subsequent survey-based estimates, but was based on a relatively small sample size of 191. Note, however, that this estimate is from a time when predator control was far more co-ordinated and intense. A more recent estimate obtained from monitoring farms set up by the wool industry suggests that 46% of all lamb mortalities are due to predation (Viljoen 2016).

Table 1. A geographical summary of results on neonatal lamb mortality derived from field necropsy surveys. Losses are expressed as % of lambs born (Source: Davies 1999).

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

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

Growing concerns about livestock depredation in South Africa led to a couple of estimates of the scale of the problem. For example, Bekker (2001, cited in Stannard 2005) estimated that 1 million sheep were being lost annually, and the National Woolgrowers Organisation (NWGA) estimated a loss of 8% (2.8 million head of small stock, 2007) of stock per year (De Waal 2007, in van Niekerk 2010). These concerns have recently led to a series of studies to quantify the problem more accurately, all based on interviews with commercial farmers. Van Niekerk (2010) telephonically interviewed 1424 farmers in the five major small livestock producing provinces – the Western Cape (published in van Niekerk *et al.* 2014), Northern Cape, Free State, Mpumalanga and Eastern Cape. Another smaller study was conducted on 58 farmers in the Laingsberg area in 2012 by Conradie & Landman (2013). Badenhorst (2014) reported on a study of 1344 cattle farmers in seven provinces. Another study involved telephonic interviews with 99 farmers in Northwest Province (Thorn *et al.* 2012) and the managers of 95 farms in Limpopo province (Thorn *et al.* 2013). Scheepers (2016) undertook a survey of 201 wildlife ranchers (all members of the Wildlife Ranchers of South Africa – WRSA) in Limpopo Province. Other studies are ongoing, including a large multi-year study in the Cape, and another study of a set of monitoring farms set up by the wool industry.

Van Niekerk (2010) and van Niekerk *et al.* (2014) estimated that predators were responsible for the losses of 6.2% to 13% of sheep and goats in the five provinces of their study (Table 2). These estimates are consistent with data obtained by Conradie & Landman (2013) for the Laingsberg area of the Karoo, which suggested that 9% of stock were lost to predation (12% were lost to all causes). Interestingly, the predation percentage for mutton sheep was greater than for wool sheep (6% on smaller farms, n=8 to 19% on larger farms, n=12) compared with 7% (n=12). This is possibly because wool sheep tend to be more actively managed (Conradie & Landman 2013). Lawson (1989) reported a lower predation rate of 3% for sheep farming in KwaZulu-Natal.

Table 2. Estimates of predation losses as a percentage of stocks based on interview data. Sources: van Niekerk (2010), Lawson (1989), Thorn *et al.* (2012, 2013), Badenhorst (2014).

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

In a study of Angora goats on stud farms, Snyman (2010) could only name a probable cause of death in 30% of deaths of pre-weaned Angora goat kids which had an average mortality rate of 11.5%. Of these, predators accounted for 39%. While this was more than any other cause, the mortality from predators (4.5%) was low relative to the rates reported for general small stock (Table 2).

Thorn *et al.* (2012, 2013) estimated losses of about 1.4-2.8% of total game and domestic livestock holdings in Limpopo and North West Provinces (Table 2). The Limpopo and North West studies included all types of farms, which were dominated by game farms. Since cattle and game present far fewer opportunities for predation than do small stock due to their size alone, one would expect lower rates of predation in their studies. Indeed, cattle farms reported by far the lowest losses, with losses in all cases being less than 1% of their herds (Table 2; Badenhorst 2014).

The overall losses reported for mixed farms in the savanna biome are very much in line with the rates of loss reported from elsewhere. For example, based on a global review, Meissner (2013) reports that domestic livestock depredation leads to annual losses of 0.2-2.6%. Many studies from the region are also in this range. For example, losses of 1.4%, 2.2%, 1.8% and 4.5% of stock holdings have been reported in Namibia, Botswana, Kenya and Tanzania, respectively (Marker *et al.* 2003, Kolowski & Holekamp 2006, Schiess-Meier *et al.* 2007, Holmerna *et al.* 2007 – in Thorn *et al.* 2012). However, it is clear that the type of farming is a very important factor. The above findings suggest that stock losses on South African commercial cattle farms are relatively small, whereas those on commercial small stock farms are high. If there is any accuracy to the perception that these predation rates are rising, then small-stock farmers in particular may be facing significant difficulties.

Communal rangelands

Livestock kept in unfenced communal grazing areas are also major targets of predators. This is evidenced from the numerous studies that have taken place in communal rangeland areas of eastern and southern Africa (Rasmussen 1999, Butler 2000, Patterson *et al.* 2004, Woodroffe *et al.* 2005, Kolowski 2006, Holmern *et al.* 2007, Lagendijk & Gusset 2008, Chaminuka *et al.* 2012. Sikhweni and Hassan 2013). Again, several authors caution that the extent of damage caused may be exaggerated, because local people affected by livestock loss fail to take into consideration other threats to livestock including disease, accidents and theft (Holmern *et al.* 2007, Kissui 2008, Dar *et al.* 2009, Dickman 2009, Atickem *et al.* 2010, Harihar *et al.* 2014). Thus studies that account for all these causes are likely to be more reliable. It is also important to note that because livestock holdings are far from normally-distributed in most cases, with a few people owing a large proportion of the overall herd, the estimates of overall, average and individual losses may differ substantially.

Many of the studies on communal rangelands have been concerned with predation levels in the areas surrounding protected areas. For example, Butler (2000) found that predators killed 5% of livestock (dominated by goats and cattle) in the Gokwe communal land area adjacent to Sengwa Wildlife Research Area, with losses amounting to 12% of income among livestock-owning households. Most of these losses were due to baboons (52%), lions (34%) and leopards (12%), and almost all predation was on goats and sheep. Similarly, losses due to livestock depredation were estimated to amount to 25% of the per capita income of farmers in Nepal (Oli *et al*. 1994). In Tanzania, stock loss to carnivores was reported by Western Serengeti villagers as two thirds of the average annual income (Borge, 2003). Around the Makgadikgadi Pans National Park in Botswana, where cattle are let out of their kraals in the morning and left unattended all day, overall losses to predators amounted to 2.2% and average losses were 5.5% (Hemson *et al*. 2009). This was mainly due to stray cattle taken at night by lions. Farmers also suffered overall losses of 3% to disease and 1% to theft. In Kenya, Patterson *et al*. (2004) estimated the predation of livestock to represent 2.6% of the herd's value.

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

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

In the same area, Hawkins (2012) investigated the outcome of a pilot study that placed eleven EcoRangers on farms to demonstrate the effects of shepherding results in low small stock losses. Unfortunately, the pilot study did not employ an experimental approach, and there was no control. However, over the one year period from August 2011 to 2012, the rangers reported 17 livestock losses, none of which were due to wild predators. Using the figures at face value, there was a loss of one small livestock unit out of total of 4496 small stock units (sheep and goats) over an area of 14852 ha (6552 ha private and 8300 ha communal land), i.e. 0.02% loss. The loss from an area of 3 290 790 ha in the Northern Cape, where shepherding was not used, was 320 times more, i.e. 6.4% loss.

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

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

Similarly, people living around the Hluhluwe-iMfolozi Park (HiP) also complain of high levels of predation (Gusset *et al.* 2008). An electrified fence that separates the park from the densely human populated surroundings encloses HiP; however, wild dogs and other large carnivores are notoriously difficult to contain within the perimeter fence. The human population around HiP consists of Zulu villagers on communal land and farmers on private land whose livelihoods largely depend on livestock and ranched wildlife, including hunting and ecotourism. Gusset *et al.* (2008) interviewed 165 villagers about introducing more wild dogs to the park. Members of the Zulu communities around the park apparently continue to persecute them outside HiP, despite formal legal protection. Similar results have been obtained in recent comparable studies on wild dogs in many parts of Africa (Kock *et al.* 1999; Breuer 2003; Davies and Du Toit 2004; McCreery and Robbins 2004; Dutson and Sillero-Zubiri 2005; Lindsey *et al.* 2005a).

Apart from the studies around protected areas, there is little information on the level of depredation of wildlife in communal land areas in the eastern half of South Africa. Given the findings of decreased predation rates with increasing distance from parks, it is likely that losses in the areas away from parks are considerably lower. Studies of these areas would make an interesting comparison with those of commercial farmers, given the differences in methods of livestock husbandry. A recent study of a small sample of 19 commercial and 23 communal farmers in Limpopo, found that commercial farms lost 1.4% of their livestock to predators (excluding game losses), compared with a loss of 0.63% in communal areas (Constant 2014). However, communal farmers reportedly lost more cattle to leopards than the commercial farmers. It should be borne in mind that the study adopted a purposive sampling strategy and snowball sampling to identify villages where communal farmers were likely to graze their livestock in leopard habitat. These two sampling techniques would have been prone to sampling bias.

Variation in livestock depredation

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

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

There has been considerable effort in the international and local literature to unravel the factors that influence predation rates. Several anecdotal accounts and statistical analyses have found that inter-annual variation in predation levels are influenced by rainfall, with most finding increases during drought and low rainfall seasons (Butler 2000, Beinart 2003, in Nattrass *et al.* 2017, Bailey & Conradie 2013, Badenhorst 2014), and others finding a positive relationship with rainfall (Patterson *et al.*, 2004). The explanation for these and other temporal patterns is usually linked to the availability of wild prey (e.g. Patterson *et al.*, 2004, Mishra *et al.*, 2003, Bagchi & Mishra, 2006).

Spatial patterns are also influenced by factors such as broad habitat types and distance from protected areas. Thorn *et al.* (2013) found that predation rates on private farmlands increased with distance from protected areas. This is the opposite of findings on large predators from communal and small-scale farming areas in other countries (Azlan & Sharma, 2006, Holmern *et al.*, 2007), and could be explained on the basis of medium-sized predators such as jackal becoming more abundant in the absence of large predators such as lion ("mesopredator release", see chapter 8). Nevertheless, there is a strong perception among many South African farmers that the proliferation of game farms has led to increased predator numbers. Stannard (2003) found that both topography and surrounding farm practice influenced predation rates.

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

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

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

Predation losses in relation to other threats

Livestock and game farmers face a range of threats, including poisoning, theft, disease and drought. For example, over 600 species of plants are known to cause poisoning of livestock in Southern Africa. Livestock losses due to plant poisoning have been estimated to amount to some 37 665 cattle (10% of expected cattle deaths) and 264 851 small stock per year (Kellerman *et al.* 1996), at a cost to the industry of about ZAR 150 million (Kellerman *et al.* 2005, Penrith *et al.* 2015).

Figures from the South African Police Service's National Stock Theft Unit (SAPS) indicate that around 15 000 - 16 000 cattle, 20 000 - 24 000 sheep and between 8 000 - 14 500 goats are stolen annually (NERPO, 2009). However, based on survey data, Scholtz & Bester 2010 estimated that these numbers are probably much higher (Table 3), with a large proportion being stolen in communal land areas. Mortality was found to be several times higher than stock theft, but sheep suffered a higher proportion of losses to stock theft. Unfortunately their survey did not distinguish depredation from other causes of mortality.

Table 3. The number of animals that die or are stolen annually on a national scale in South Africa, estimated from the results of the survey; on private and communal land. Source: Scholtz & Bester 2010

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

Nevertheless, Scholtz & Bester (2010) argued that stock theft, problem animals and vermin were the main reasons for the decline in livestock numbers over the previous decade, by causing farmers to invest in other agricultural enterprises. However it is likely that the introduction of social welfare grants and changing culture are the primary reasons for reduction of farming activities in communal land areas, and that stringent labour laws have played a major role in private land areas. This decrease in the numbers of livestock is in itself important to consider, as it means that decreasing numbers of households are affected by stock losses.

The three main threats that are faced by South African small livestock producers are drought, theft, and predators (De Waal & Avenant 2008). Among the mixed sample of mainly game farmers interviewed by Thorn *et al.* (2012), 32% considered poaching the most costly source of economic loss, followed by drought (30%), predation (19%), fire (11%) and game or livestock diseases (8%). Among small stock farmers interviewed by Stannard (2003), on the other hand, losses due to livestock theft were considered to be relatively small in comparison to the predation on small livestock.

In communal areas, the overall losses, including from other causes, are particularly high. Around Kruger Park, the predation losses of 8% reported by (Chaminuka et al. 2012) added to the reported 12.7% of cattle that died from disease, while the losses of 11% in Mhinga District were one of myriad problems faced by the farmers, who also suffered high losses to disease (23%) and theft (3%). In Limpopo, while predation was the main cause of livestock losses (65%), significant numbers were also lost to disease (18%), theft (13%) and accidental deaths (3%), with no significant differences in the proportions of these between communal and commercial farms.

In light of the above, one of the shortcomings of estimates of predation impacts is that they do not consider the counterfactual: what losses would have been incurred in the absence of predators? At the very least, it might be expected that there would have been some natural mortality among the animals that had been predated, especially given that these are often the weaker or sicker animals. While no work has been done to answer this question per se, perhaps the best indication comes from work done on an experimental farm set up by government, academic institutions and the wool industry. Strauss (2009) analysed predation data from the Free State Wool Sheep Project established in 1998. Set up to compare different production strategies, it was realised fairly early in the project that predation by jackal, caracal and stray dogs was a significant problem. The findings showed that both merino and dorper sheep suffered heavy losses when kept in the veld, though these appeared to be ameliorated by kraaling at night. Predation losses were close to zero for the sheep kept on planted pastures for part of the year (Strauss 2009, **Error! Reference source not found.**). Overall merino post-weaning losses to predation ranged from 6.7 to 26.3% per annum (average 18.6%), compared to 0.9%, 3.0% and 1.3% losses to disease, metabolic disorder and accident, and theft, respectively. Most of the post-weaned losses were 4-12 months, but older, and especially pregnant, ewes were also vulnerable. The results of this study suggest that when management actions reduce the risk of predation, a substantial proportion of the avoided predation losses become lost to other causes. This substantiates the hypothesis that a 10% reduction in predation will not result in a 10% reduction in losses.

In this example, a 23% reduction in predation losses resulted in a net reduction in overall losses of 10%, and 51-54% reduction in predation led to net reductions in losses of 27-37% (net losses = 0.727*reduction in predation losses - 5.8871, n=4, R^2 = 0.95).

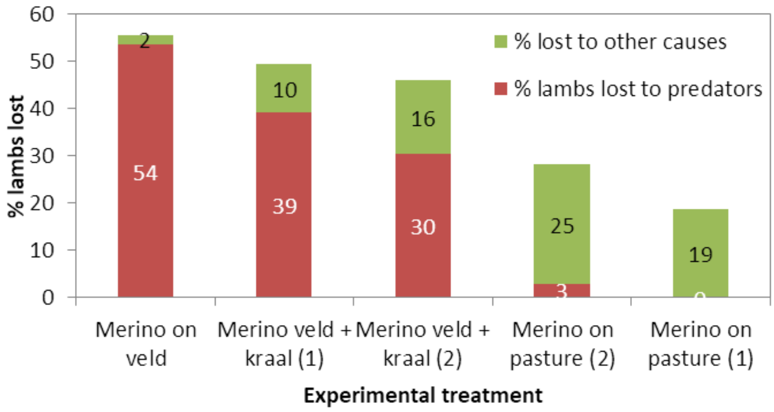

Figure 4. Percentage of lambs lost to predation or other causes before weaning in five experimental areas of the Free State Wool Sheep Project (Data extracted from Strauss 2009)

Farmer's options and responses

Farmers can opt to try and eliminate predators through lethal methods, or to protect their stock from predators using non-lethal methods, or they can use a combination of these. Lethal methods include shooting, hunting with dogs, setting snares, trapping and poisoning (Arnold 2001, Moberly 2002, van Deventer 2008, Van Niekerk *et al.* 2014). Shooting can be done by the farmers themselves or by professional hunters that are paid by the farmer. Hunting with dogs is also effective, but is more costly because of the costs of acquiring, training and maintaining the dogs. Poisoning is cheap and easy, but it is not species-specific and results in the unnecessary and painful deaths of non-problem animals. A variety of traps is also used, including cages, boxes, leg-hold traps and snares. Use of traps is also widespread and considered to be cost-effective, but is somewhat more labour-intensive if farmers are concerned about preventing unnecessary suffering, as the traps have to be checked regularly. Legal restrictions on the use of lethal methods are discussed in Chapter X. This includes not only the methods but the species targeted. For example, cheetahs, leopards, lions, spotted hyaena, brown hyaenas and African wild dogs were listed as protected species in 2005 and can only be captured or destroyed under permit from the provincial conservation authorities.

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

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

The use of guarding animals has been posed as a labour-saving solution to protecting livestock, and has been tested with varying success. Anatolian dogs are the most popular choice, but are expensive to obtain and are only effective against smaller predators (Snow 2006). Nevertheless, the results of trial programmes in Namibia, Australia and South Africa suggest that this is a highly effective method (Marker *et al.* 2005, van Bommel & Johnson 2011, McManus *et al.* 2015). One of the main drawbacks is that the dogs do need to be fed and monitored.

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

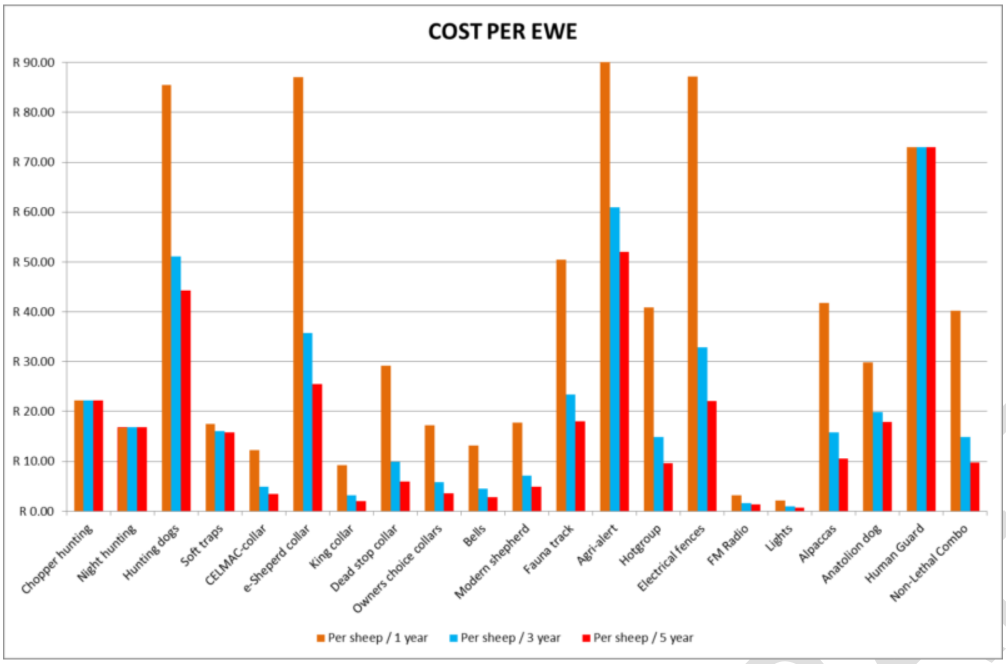

Figure 5. Relative costs of lethal and non-lethal methods for a typical Karoo farm of 6000 ha with 1000 ewes in three herds (dry, laming and replacement). Source: http://www.pmfsa.co.za/home/detection-prevention.

It is not surprising therefore, that most commercial farmers still employ lethal methods in their efforts to reduce predation risk. Nevertheless, the majority of farmers that engage in predator management do use some non-lethal methods as well. Predator control in general is more prevalent among small stock farmers than cattle farmers and game farmers. Badenhorst (2014) found that the proportion of cattle farmers engaging in any form of predator control ranged from 37% and 66% in six provinces (average 52%), but was only 4% in the Eastern Cape. Most small stock farmers, on the other hand, engage in practices to reduce predation risk. Between 60 and 90% of small-stock farmers in 5 provinces (average 74%) practice lethal methods, while 44-87% (average 67%) practice non-lethal methods (Figure 6).

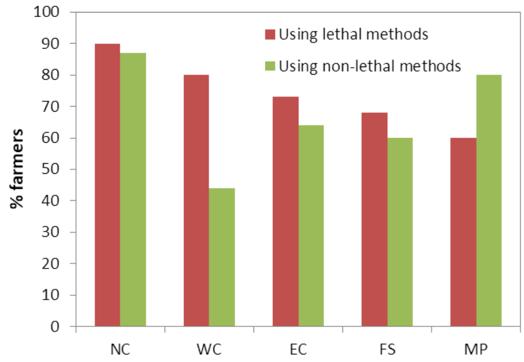

Figure 6. % small stock farmers using lethal and non-lethal methods in 5 provinces (Source: van Niekerk et al. 2010)

Shooting has tended to be the most popular option on both small-stock and cattle farms (Figure 7), although it is no longer considered as effective as it used to be (B. Conradie, pers. comm.). Poisoning, despite being illegal was still commonly practiced at the time of the surveys, particularly in the Northern Cape.

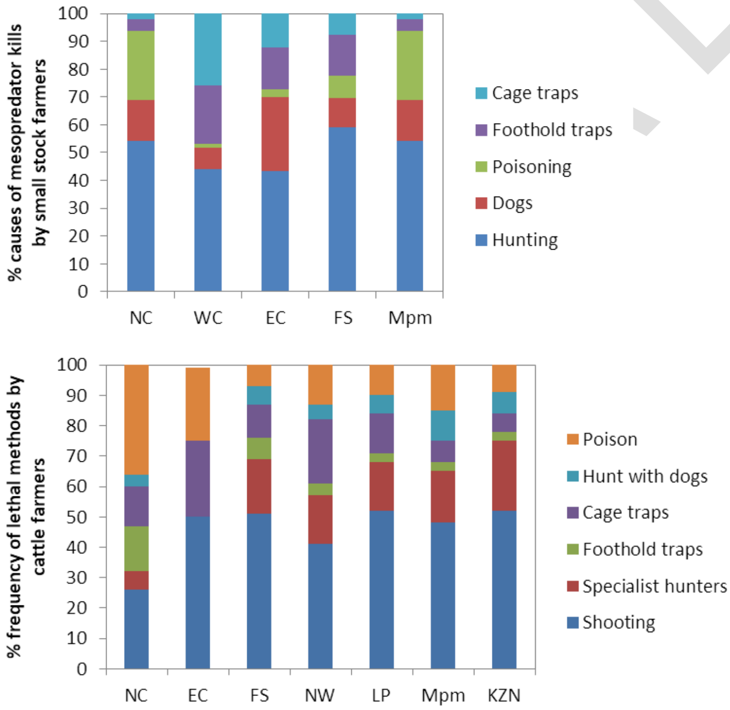

Figure 7. Indications of the relative use of different types of lethal methods on small-stock and cattle farms, based on data in van Niekerk et al. (2010) and Badenhorst (2014)

Herding and kraaling are the most common non-lethal methods used to protect wildlife against predators, both among small-stock and cattle farmers (Figure 8).

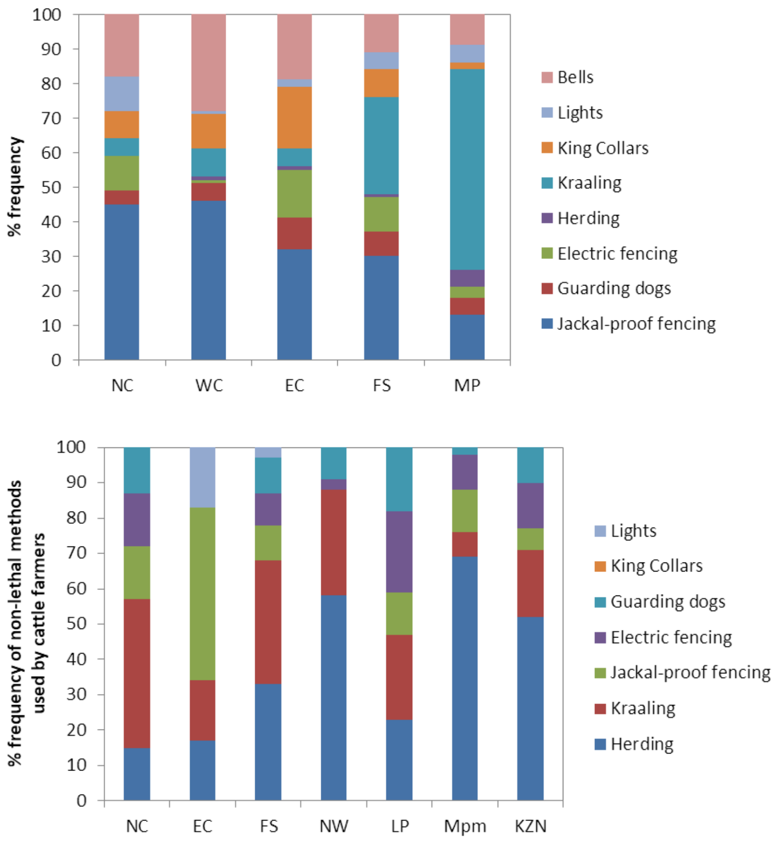

Figure 8. Indications of the relative use of different types of non-lethal methods by small stock farmers (above), and cattle farmers, based on data in van Niekerk (2010) and Badenhorst (2014)

In Limpopo province, Thorn *et al.* (2013) found that lethal and non-lethal methods were practiced at 47% and 79% of farms respectively (35% using both), and 15% of farms (all extensive game farmers) used neither. Non-lethal methods included fenced enclosures, moving potential prey animals to open areas with a lower risk of predation and natural anti-predator adaptations (stocking native, predator-adapted breeds and not dehorning livestock). In the North West Province 67% of farmers practiced lethal control of carnivores (Thorn *et al.* 2012), while 63% used non-lethal methods, and 32% used both. A greater range of lethal methods was reported, including poisoning and trapping. Non-lethal deterrents included protective enclosures, guard dogs and human guards. 16% of farmers did not use any methods. In this context it is important to note that there has also been a rise in “weekend farmers" (Reed & Kleynhans 2006, Wessels & Willemse 2013) who may be less inclined to take action against predators.

Thorn *et al.* (2013) found that lethal control tended to be practiced to a much greater extent by certain cultural groups, which was a much greater determinant than actual financial losses. They found that the odds of a farmer practicing lethal control were about 19 times greater among Afrikaans-speaking farmers and about 7 times greater among English-speaking farmers, compared to Setswana-speaking farmers. Lindsey *et al.* (2005) also found that Afrikaans-speaking farmers and older people were less tolerant of carnivores. However, in these areas it is quite possible that these farmers happened to be the small-stock farmers and therefore had more reason to be less tolerant.

Few studies have obtained information on the expenditure by farmers on predator control. Among cattle farmers, who suffer relatively low losses compared to other stock types, average annual expenditures in each province ranged from R0.39 to R8.94 per head on lethal measures, and from R0.89 to R25.13 per head on non-lethal measures (Table 4; Badenhorst 2014). There was no relationship between expenditure and the percentage losses in each province. In the North West, expenditure on these measures was about a quarter of the value of the losses incurred (Badenhorst 2014).

Table 4. Expenditure on lethal and non-lethal measures by cattle farmers (source: Badenhorst 2014)

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

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

Cost effectiveness of predator management

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

For example, analyses of hunting club records, which span multiple farms over multiple years, have suggested that caracal culling actually increased subsequent livestock losses when compared to farms where fewer caracals were culled (Bailey & Conradie 2012; Conradie & Piesse 2013), whereas culling vagrant dogs would reduce the likelihood of future losses. Van Niekerk *et al.* (2013) found that use of professional hunters was ineffective, and that kraaling small stock at night in the Western Cape had a significant positive effect on the level of predation on a farm. The latter was thought to be due to the fact that damage-causing animals learn to infiltrate closed areas and cause major losses, especially where fences are not up to standard. However, a high level of success was experienced when non-lethal methods are used in combination or in rotation with one another, probably due to the adaptability of predators (van Niekerk *et al.* 2013). In a study of cattle farms in the North

West Province, Badenhorst (2014) found that specialist hunter, hunting with dogs and guarding animals, all had a positive relationship with occurrence of predation, while other lethal methods had no significant effects. Even if this signifies a retaliatory response, it does call into question the effectiveness of these methods. Nevertheless, limited conclusions can be drawn from these studies, and the issue is examined in more detail in Chapter 6.

The economics of lethal versus non-lethal predator management was explored by McManus *et al.* 2014 in a short (3-year) experiment conducted on 11 farms in the Swartberg region of the Karoo (McManus *et al.* 2014). The farmers in the study continued to use lethal controls in the first year (mostly gin traps, except for two farms that used gun-traps and hunting, respectively), then switched to guardian alpacas and dogs for the following two years. The study results suggested that non-lethal controls were significantly cheaper and four times as effective as lethal controls (Table 5). These findings agree with those of other studies. For example, in a study of 10 farms, Herselman (2005) found that the percentage of lambs caught before weaning decreased from 7.6% to 2.6% two years after the introduction of guard animals. However, a follow-up study showed that many of the farmers in the McManus study had resorted to using lethal methods again (http://www.travel-hack.com). If the conclusions about cost-effectiveness were accurate, then this suggests that the choice of methods was also driven by other factors, such as the emotional response to predators that harm their livestock or a cultural affinity to the use of lethal methods.

Table 5. Results of a three year experiment on 11 Karoo farms

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

Source: McManus *et al.* 2014

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

Economic impacts of livestock depredation

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

Recent studies of predation losses in South Africa's commercial farms are relatively comprehensive in their coverage, and suggest that aggregate losses of livestock amount to R2.8 billion per annum, with losses of at least R2.34 billion to small stock farmers (1.39 billion in 2007), and R479 million to cattle farmers (R383 million in 2012). In addition, losses from South Africa's 11 500 game farms (DAFF 2016) and from small-scale and communal farming areas could also be substantial, and likely to bring the total to over R3 billion. Estimates still vary, however. For example, Thorn *et al.* (2012) estimated total losses of R68 million to all farm types in North West Province, whereas Badenhorst (2014) estimated losses of R84 million for cattle farms alone in the same province. McManus et al (2014) also questioned the disparity between estimates of Statistics South Africa (2010) based on the 2007 agricultural census, and those of van Niekerk (2010), which were nearly eight times higher. Nevertheless, van Niekerk was conservative in his estimates of value: whereas some authors advocate using the value of the "finished product" (sensu McInerney 1987, Moberly 2002), i.e. the income that would have been derived from the animal had it survived, van Niekerk used the replacement value of animals lost - (R600 for young stock and R1000 for older animals).

The Agriculture, Forestry and Fisheries sector contributed R94.4 billion to GDP in 2016, or 2.4% of GDP[1] (DAFF 2017). Agriculture makes up about 80% of this (Stats SA 2013). Animal production makes up about 49% of the gross value of agriculture production, with crops and horticulture making up the balance. Free-ranging livestock contributed about 33% of animal production value and therefore about 16% of gross agriculture production value. The gross production value of free ranging livestock was about R39.75 billion in 2016. Based on these figures, the direct contribution to GDP would be in the order of R12.3 – 14.7 billion[2] to GDP. Overall impacts on GDP, taking economic linkages and induced spending effects into account, are about double this. Therefore losses in the formal livestock sector (~R3 billion) amount to an estimated 7% of its gross production value. Assuming that in the absence of predators about 50% of these animals would be lost to other causes (see above), the loss amounts to about 0.5% of the Agriculture Forestry and Fishing Sector GDP and 0.01% of national GDP, or 0.02% if multiplier effects are included. Even if game losses and livestock losses in the small scale and subsistence sectors were taken into account, and if expenditures on predator control were also included, the overall impacts would be fairly small when viewed in the context of the national economy.

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

Impacts on the viability of farming are likely to vary among different types of farms as well as individual farms, depending on their geographical and social context. Thorn *et al.* (2012, 2013) found that livestock predation losses were generally not sufficient to threaten farming livelihoods or the economies of the North West and Limpopo provinces. In the North West, predation losses amounted to a very low proportion of annual net operating profits for farms in the North West (0.22–0.29% for game farms, 0.46–0.73% for cattle farms and 0.37% for

[1] Contribution to VAD has been 2-2.1 from 2010 to 2015, but rose to 2.4 in 2016

[2] Lower estimate is 16% of sectoral contribution, upper estimate based on most recent estimate of multipliers for livestock products (Conningarth Economists 2015)

sheep farms, and only 0.2% of provincial agricultural GDP; Thorn *et al.* 2012). Stannard (2003) felt that the predator problem was not a general threat to small livestock production in South Africa. However, van Niekerk (2010) concluded that the high losses reported on small stock farms constituted a threat to their viability. Most studies suggest that predation is highly variable, and may be a significant problem for a small proportion of farmers. In addition, game farms stocking high value ungulates might suffer disproportionately high financial losses from relatively low predation frequencies.

These are the areas over which farmers have (constrained) choices in the long run (stock type), medium run (non-lethal control practices like fencing) and short run (lethal predator control practices like hunting). In the short to medium run, farmers make decisions about how much to invest in lethal and non-lethal control methods based on the information they have at hand. But in the longer run, if losses are persistently high, this could have an impact on the nature of farming. Where certain types of farming have become unviable in the past, this has led to changes in land use. For example, high rates of stock theft led to a change from beef to dairy farming in KwaZulu-Natal (Turpie *et al.* 2003). Predation may also have played some role in the rapid and extensive transition to game farming that has taken place in South Africa, along with other market forces and the introduction of legislation to encourage this activity. The impacts of these changes have not been properly studied, but they do not appear to have resulted in catastrophic losses in production or employment, and may even have had positive impacts on GDP, since game ranching tends to be more profitable than livestock farming (Bothma 2005).

Social consequences

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

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

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

Another hidden cost is that felt by society more generally. The impact of predator management in livestock farming areas on biodiversity also needs to be considered, since this affects society too. Farmer responses to wildlife damage are considered by many to be disproportionate or even extreme, especially by those members of society that derive a sense of wellbeing from the existence of wild nature. For example, in the 1980s, 7000 cheetahs were killed in Namibia to protect livestock, even though reports of livestock depredation were rare (Marker 2002, Marker *et al.* 2003). In South Africa, the killing of leopards by farmers has also unleashed public outcry. The funding provided to non-profit organisations that promote non-lethal methods of predator control in South Africa are an expression of this publicly-held value.

Conclusions

It is clear from the literature that losses incurred by farmers as a result of predators are widespread and common, though highly variable across individual farms and the landscape as a whole. Collectively, these losses add up to billions of Rands, and amount to a substantial proportion of agricultural output value, but they do need to be seen in perspective in that without predators, a significant portion of these losses might still occur due to other forms of natural mortality. Given the small contribution of this sector to GDP, the overall losses are not significant at regional or national scales. Nevertheless, they may be of local economic and social significance, particularly in the arid areas of the Karoo and in certain communal rangeland areas. In areas where farming is marginal and households are poor, high levels of predation could have significant welfare impacts and could also contribute to social disharmony.

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

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

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