THE ECONOMIC COST OF LARGE STOCK PREDATION IN THE NORTH WEST PROVINCE OF SOUTH AFRICA

by

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Submitted in partial fulfilment of the requirements for the degree

M.Sc. Agric.

In the

Department of Agricultural Economics

Faculty of Natural and Agricultural Sciences

University of the Free State

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July 2014

Declaration

I declare that the dissertation for the Magister Scientiae Agriculturae (M.Sc. Agric.) degree in Agricultural Economics in the Department of Agricultural Economics, University of the Free State, is my own independent work and has not previously been submitted, either as a whole or in part, for a qualification at another university or at another faculty at this university. I also hereby cede copyright of this dissertation to the University of the Free State.

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July 2014

Acknowledgements

The author would like to thank all who made this study possible, especially the following persons:

The Red Meat Producers' Organisation (RPO) for supporting the study and the RMRD SA for providing funds to complete this study.

The responding farmers who provided valuable information for the study. Without their contributions the study would not have been possible.

My supervisor, Mr. Walter van Niekerk for his guidance, faith, friendship, encouragement and time. My co-supervisors, Dr. Henry Jordaan, Dr. Dirkie Strydom and a special word of thanks to Prof. HO de Waal, for his knowledge in the field of study and the assistance of ALPRU for providing me with the opportunity of further my education.

Mrs. Hester Linde of the Department of Animal, Wildlife and Grassland Sciences for preparing and printing the final copy of the dissertation.

The staff members of the Department of Agricultural Economics for their friendship and support throughout my few years at the University of the Free State.

Special thanks to my beloved wife Elmarie Badenhorst, for sacrificing time and attention over the past two years and for her patience and support. To my parents, Coenie and Elize Badenhorst, for their support and encouragement and for the example they have always set.

Finally, and most importantly, I would thank God for giving me the talent, wisdom and inner strength to complete this study.

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Abstract

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Abstract

Predation is a problem for livestock farmers in many parts of the world and increasing losses are ascribed to predation. The black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) are two important medium size predator species among South African wildlife, but they have a negative impact on the livestock industry in South Africa, especially on small livestock such as sheep and goats. These two predators and also brown hyaena (*Parahyaena brunnea*), cheetah (*Acinonyx jubatus*), dogs (*Canis familiaris*) and leopard (*Panthera pardus*) are responsible for losses of small and large livestock in several provinces.

A number of studies have focused on the cost of predation on small livestock, specifically the direct cost of predation, and only a few studies have looked at the different methods to help farmers to minimise or eliminate losses due to predation. However, no study has quantified the direct as well as the indirect cost of predation on cattle in South Africa.

The study focussed on predation losses of cattle in South Africa. A sample of 1 500 cattle farmers was divided between provinces in relation to the number of cattle in provinces as percentage of the national cattle herd. The Western Cape and Gauteng did not want to participate in the study; the structured questionnaire was used to conduct a survey by telephone with the remaining sample size of 1 344 cattle farmers in seven (7) provinces.

For the purpose of this report (dissertation) only the North West province was explored in detail and the primary information for the six other provinces are included as appendices.

Three main objectives were pursued, namely: to quantify the direct and indirect losses ascribed to predation; to determine the impact of predation on the large livestock industry in the North West province; to investigate the underlying structures in the predation prevention practices used by farmers in the North West province; to improve the understanding of the current behaviour of the farmers in preventing predation, and to investigate the factors that influence predation in the North West province, in order to identify prevention approaches that are associated with reduced predation. Such information may contribute to the identification of possible best management practices for predation prevention.

The study (reported in the dissertation) was conducted in the four magisterial districts of the North West province namely: Bojanala Platinum District, Bophirima District, Ngaka Modiri Molema District and Southern District. The sample size of this study was 238 respondents who farmed commercially with a total of 122 780 head of cattle or 16% of the total number of cattle in the North West province. Telephonic interviews were used to collect data from the farmers. The structured questionnaire included questions on topics such socio-economic factors, managerial factors and the methods used to protect the livestock.

The majority of the losses in the four magisterial districts of the North West province were caused by the black-backed jackal followed by the caracal. The percentage of losses due to the caracal is markedly lower than those caused by the black-backed jackal. The reason for the lower predation is not clear, but it is speculated that it may be a result of the smaller population of the caracal and the fact that caracal are solitary predators and do not hunt in groups.

The direct cost of predation losses (cattle) in the North West province was estimated at ZAR67 776 800, when extrapolating predation losses on a provincial basis. The indirect cost of predation in the North West province was divided into a lethal cost of predation (ZAR7 455 333) and the non-lethal cost (ZAR9 087 653). Therefore, the total cost of predation in the North West province was estimated at ZAR84 319 786.

This study showed that 37% of farmers in the North West province use lethal control methods and only 14% use non-lethal methods of control. The lethal preventing methods are divided into six types of methods that include: shooting predators at night with spotlights (15%), using specialist hunters (6%), foothold traps (1%), cage traps (8%), hunting with dogs (2%) and poison (5%). The non-lethal methods are: herdsmen (8%), electric fences (1%), jackal proof fences (<1%), kraaling (4%) and guarding dogs (1%).

The list of methods available in the toolkit for farmers to manage predation on cattle is shorter than for sheep and goat farmers. Most appropriate methods available to farmers to control predation or mitigate the impact of predation (non-lethal and lethal) on cattle were used by respondents. However, none of these methods when used individually or when a few were used in combination, proved to be a one-for-all solution at the provincial level. At the district level there were indications that some methods were more effective in reducing the impact of predation. The information suggests that all the appropriate methods and equipment available must be incorporated in the local predation management approach and strategy.

The data were used to investigate the underlying structures and also to identify the best management practices. The principal component regression (PCR) tools were used to analyse the data and deal with the problem of multi co-linearity. The Pairwise Granger Causality test was used to analyse the direction of causality. The study included 42 different explanatory variables that were divided into four groups namely: socio-economic factors, managerial factors, lethal control methods and non-lethal control methods. There were 11 significant variables in the PCR (Logit) and 22 significant variables in the PCR (Truncated). The causality tests showed that none of the Logit variables had a Granger cause, but there were two Tobit variables that had a Granger cause. These two lethal methods had a negative effect on the level of predation. These results were unexpected, but this effect may be because of inexperienced farmers who kill predators that do not cause problems thereby causing a "vacuum" effect of new predators moving in.

The conclusions of Van Niekerk (2010) were confirmed, namely the factors that affect the occurrence of predation and those factors that affect the level of predation are not the same. This study does not provide definitive answers to predation, but it helps to understand predation better with a view to develop appropriate management solutions.

The total direct and indirect cost of predation on cattle in the different provinces and South Africa was: Western Cape - NA; Northern Cape - ZAR19 943 079; Free State - ZAR117 600 433; Eastern Cape - ZAR4 827 237; KwaZulu-Natal - ZAR66 027 879; Mpumalanga - ZAR43 938 376; Limpopo - ZAR46 486 017; Gauteng - NA; North West - ZAR84 319 786; **South Africa - ZAR383 142 807**.

In summary, the respondents in six (6) of the seven (7) provinces ascribed the majority of the predation losses on cattle to the black-backed jackal. The exception was the Limpopo province where the leopard was implicated to account for most of the predation losses on cattle. In some provinces the second most predation losses were ascribed either to the caracal, brown hyaena, leopard, dogs or cheetah.

It should be noted that some uncertainty may exist in the ability of farmers to identify positively the specific predator responsible for the losses. In some cases secondary scavenging on cattle may also have been mistaken for predation. It clearly calls for increased efforts to increase the skills of farmers to identify the specific methods used by predators to catch and eat their prey.

The widespread negative impact of predation losses to sheep, goats and cattle can hardly be ignored any longer. A third study by the UFS will soon commence to estimate the impact of predation on the wildlife ranching sector. Currently the approach to manage predation is fragmented and uncoordinated. The scale and impact of predation in South Africa calls for a focused and coordinated predation management and research programme to reduce (mitigate) the negative impact of predation.

Samevatting

DIE EKONOMIESE KOSTE VAN GROOTVEE PREDASIE IN DIE NOORDWES PROVINSIE VAN SUID-AFRIKA

deur

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Samevatting

Predasie is ‘n probleem vir veeboere in baie dele van die wêreld en veeverliese word toenemende aan predasie toegedig. Die rooijakkals (*Canis mesomelas*) en rooikat (*Caracal caracal*) is belangrike middelslag roofdierspesies wat deel vorm van die Suid-Afrikaanse wildlewe, maar hulle het ‘n negatiewe impak het op die veebedryf in Suid-Afrika, veral op kleinvee soos skape en bokke. Die twee roofdiere sowel as bruin hiëna (*Parahyaena brunnea*), jagluiperd (*Acinonyx jubatus*), honde (*Canis familiaris*) en luiperd (*Panthera pardus*) is verantwoordelik vir verliese van klein- en grootvee in verskeie provinsies.

Vele studies het op die koste van predasie op kleinvee, spesifiek die direkte koste van predasie gefokus en slegs ‘n paar studies het ondersoek ingestel na die verskillende metodes om boere te help om die kostes van predasieverliese te verminder of elimineer. Daar was egter nog nie ‘n studie wat die direkte koste sowel as die indirekte koste van predasie op grootvee in Suid-Afrika gekwantifiseer het nie.

Die studie het op predasieverliese van beeste in Suid-Afrika gefokus. ŉ Monter van 1 500 beesboere is tussen provinsies verdeel in verhouding tot die provinsiale beesgetalle as persentasie van die nasionale beeskudde. Die Weskaap en Gauteng wou nie aan die studie deelneem nie; ŉ gestruktureerde vraelys is gebruik om ŉ telefoniese opname by die oorblywende monter van 1 344 beesboere in sewe (7) provinsies uit te voer.

Vir die doel van die verslag (verhandeling) is slegs die Noordwes provinsie in detail ontleed en die primêre inligting vir die ander ses provinsies word as aanhangsels aangebied.

Drie hoof doelwitte is nagestreef, naamlik: om die direkte en indirekte kostes wat aan predasie toegeskryf word te kwantifiseer; om die impak van predasie op die grootvee bedryf in die Noordwes provisie te bepaal; om die onderliggende strukture van die voorkomingspraktyke wat boere in die Noordwes provinsie gebruik te ondersoek; om die bestaande optredes van die boere om predasie te voorkom te verbeter en om die faktore wat predasie in die Noordwes provinsie beïnvloed te ondersoek, om voorkomingspraktyke te identifiseer wat verlaagde predasie tot gevolg gaan hê. Hierdie inligting kan bydra tot die identifisering van moontlike bestuurspraktyke vir predasie voorkoming.

Die studie (in die verhandeling bespreek) is in die vier landdrosdistrikte van die Noordwes provinsie uitgevoer, naamlik: Bojanala Platinum distrik, Bophirima Distrik, Ngaka Modiri Molema Distrik en Suidelike Distrik. Die steekproef grootte was 238 respondente wat kommersieel met 122 780 beeste boer of 10% van die totale aantal beeste in die Noordwes provinsie. Telefoniese onderhoude is gebruik om die data by die boere in te samel. Die vraelys het vrae oor sosio-ekonomiese faktore, bestuursfaktore en die metodes wat gebruik word om hulle vee te beskerm ingesluit.

Die meerderheid van die verliese in die vier landdrosdistrikte van die Noordwes provinsie is veroorsaak deur die rooijakkals gevolg deur die rooikat. Die persentasie verliese veroorsaak deur die rooikat is aansienlik minder as die deur rooijakkalse. Die rede vir die laer predasie is nie duidelik nie, maar daar is gespekuleer dat dit aan ŉ kleiner populasie van rooikatte toegeskryf kan word en ook die feit dat rooikatte alleenlopende roofdiere is en nie in groepe jag nie.

Die direkte koste van predasieverliese (beeste) in die Noordwes provinsie is geraam op ZAR67 776 800, wanneer verliese op provinsiale basisse geëkstrapoleer word. Die indirekte koste van predasie in die Noordwes provinsie is verdeel in dodelik kostes (ZAR7 455 333) en die nie-dodelike kostes (ZAR9 087 653). Dus was die totale koste van predasie in die Noord Wes provinsie geraam op ZAR84 319 786.

Hierdie studie het getoon dat 37% van die boere in die Noordwes provinsie dodelike beheermetodes en slegs 14% nie-dodelike metodes gebruik. Die boere in die Noordwes provinsie gebruik tans ses tipes dodelike voorkomings metodes wat insluit: skiet van roofdiere in die nag met kolligte (15%), gebruik van spesialis jagters (6%), vangysters (1%), vanghokke (8%), jage met honde (2%) en gif (5%). Die nie-dodelike metodes is: veewagters (8%), geëlektrifiseerde heinings (1%), jakkalswerende heinings (<1%), krale (4%) en waghonde (1%).

Die lys beskikbare metodes vir boere in die gereedskapkis om predasie op beeste te bestuur is minder as vir skaap- en bokboere. Meeste toepaslike metodes wat beskikbaar is om predasie op beeste te beheer of die impak te verminder (nie-dodelik en dodelik) word deur respondente gebruik. Nietemin is geen van die metodes wat indiwidueel of gesamentlik gebruik word, ͗n magiese oplossing vir predasie op die provinsiale vlak nie. Op die distriksvlak was wel aanduidings dat sommige metodes meer effektief was om die impak van predasie te verminder. Die inligting suggereer dat al die toepaslike metodes en toerusting beskikbaar moet wees om predasie op die plaaslike vlak vir predasiebestuur en -strategie aan te wend.

Die data is gebruik om die onderliggende strukture te ondersoek en om die beste bestuurspraktyke te identifiseer. Die hoofkomponenteregressie (PCR) is gebruik om die data te analiseer en om die probleem van multikolineariteit op te los. Die Pairwise Granger Causality toets is gebruik om die rigting van kousaliteit te analiseer. Die studie het 42 verskillende verduidelikende veranderlikes bevat wat in vier groepe verdeel is naamlik: sosio-ekonomiese faktore, bestuursfaktore, dodelike beheermetodes en nie-dodelike beheermetodes. Daar was 11 beduidende veranderlikes in die PCR (Logit) en 22 beduidende veranderlikes in die PCR (Truncated). Die kousaliteit toets het gewys dat geen van die Logit veranderlikes ‘n Granger oorsaak het nie, maar daar was twee Tobit veranderlikes wat ‘n Granger veroorsaak het. Hierdie twee dodelike metodes het ‘n negatiewe effek op die vlak van predasie. Hierdie uitslae was onverwags, maar die effek kon veroorsaak word deur onervare boere wat roofdiere doodmaak wat nie probleme veroorsaak nie en sodoende ‘n “vakuum” effek veroorsaak en nuwe roofdiere inbeweeg.

Die gevolgtrekking deur Van Niekerk (2010) is bevestig, naamlik die faktore wat die voorkoms van predasie beïnvloed verskil van die faktore wat die vlak van predasie beïnvloed. Die studie bied nie ŉ finale antwoord nie maar help om predasie beter te verstaan met die oog daarop om toepaslike bestuursoplossings te ontwikkel.

Die totale direkte en indirekte koste van predasie op beeste in verskillende provinsies en Suid-Afrika was: Weskaap - NB; Noordkaap - ZAR19 943 079; Vrystaat - ZAR117 600 433; Ooskaap - ZAR4 827 237; KwaZulu-Natal - ZAR66 027 879; Mpumalanga - ZAR43 938 376; Limpopo - ZAR46 486 017; Gauteng - NB; Noordwes - ZAR84 319 786; **Suid-Afrika - ZAR383 142 807**.

Die respondente in ses (6) van die sewe (7) provinsies het meeste van die predasieverliese op beeste aan rooijakkalse toegeskryf. Die uitsondering was die Limpopo provinsie waar die luiperd verantwoordelik gehou is vir meeste verliese onder beeste. In party provinsies was die tweede meeste verliese aan rooikatte, bruin hiëna, luiperd, honde of jagluiperd toegeskryf.

Daar mag ŉ mate van onduidelikheid wees in die vermoë van boere om die spesifieke roofdier wat skade aanrig positief te identifiseer. Soms mag sekondêre aas op karkasse met predasie verwar word. Duidelik moet pogings aangewend word om die vermoë van boere om spesifieke metodes van roofdiere om prooi te vang en vreet, te verbeter.

Die wydverspreide negatiewe impak van predasieverliese op skape, bokke en beeste kan nie langer geïgnoreer word nie. ŉ Derde studie deur die UV begin eersdaags om die impak van predasie op die wildbedryf te bepaal. Die huidige benadering tot predasiebestuur is gefragmenteerd en ongekoördineerd. Die omvang en impak van predasie in Suid-Afrika vereis duidelik ŉ doelgerigte en gekoördineerde predasiebestuurs- en navorsingsprogram om die omvang en negatiewe impak van predasie te verminder.

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Chapter 1
Introduction

1.1 Background

Predation is an age old problem in many parts of the world and livestock farmers suffer increasing losses due to predation. The word predation can be defined as a biological interaction where a predator (an organism that is hunting) feeds on its prey (an organism that is attacked) (Begon, Townsend & Harper, 1996). Predation on livestock is a growing problem for farmers and producers across the world. For example, coyote (*Canis latrans*) kill sheep and goats in parts of North America (USA and Canada) (Thorn, Green, Dalerum, Bateman & Scott, 2012). Wolverines (*Gulo gulo*) kill sheep and domestic reindeer in Norway (Landa, Fudvangen, Swenson & Roskaft, 1999). Livestock producers have been protecting livestock for centuries by fencing and kraaling to reduce the risk of predation losses. Black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) are important medium size predator species among South African wildlife, but they have a negative impact on the livestock industry in South Africa (De Waal, 2009), especially small livestock such as sheep and goats (Hall-Martin, Botha, 1980; De Waal, 2009). These two predators and also brown hyaena (*Parahyaena brunnea*), cheetah (*Acinonyx jubatus*), dogs (*Canis familiaris*) and leopard (*Panthera pardus*) are responsible for losses of small livestock and cattle in South Africa (De Waal, 2009).

Livestock producers in South Africa protect their livestock by using various techniques, including non-lethal and lethal methods, to reduce and prevent predation. Until the early 1990's the official system of predator control in South Africa was conducted by predator hunting clubs, with the active participation of farmers (Stadler, 2006; Gunter, 2008; De Waal, 2009). With reference to two of the hunting clubs, namely the Ceres and "Oranjejag" clubs that operated from the mid- 1970 to the mid- 1990, the farmers were officially assisted with predator control activities and predators were managed (Gunter, 2008). The hunting clubs were funded by the government until the mid- 1990, when the government returned the primary responsibility of predation management back to the farmers and predator numbers allegedly increased again (Conradie, 2012).

According to Shwiff & Bodenchuk (2004) management of predation is a controversial and often misunderstood reality of livestock management. Management and control of predators on a farm are very important during the lambing and calving seasons. In order to reduce predation farmers must use the methods that work best during the lambing and calving seasons. In some cases the method that works best on a specific farm is prohibited by legislation, which may cause intense debate regarding predator control on livestock farms in South Africa. It is understandable that farmers are upset about new legislation which prohibits the use of preferred control methods such as poison and trapping in footpaths (Schneekluth, 2011). Farmers had to adapt and use non-lethal control methods to keep their livestock safe and reduce the negative effects on biodiversity. The non-lethal methods include fences (conventional and electric), visual repellents, livestock protection collars, management and guarding animals. The lethal control methods include trapping, shooting, poison baiting, livestock protection collars and sport hunting. Although farmers use all these management techniques the losses ascribed to predation are still very high (Strauss, 2009; Van Niekerk, 2010). The impact of small livestock losses appears to have forced many South African farmers to change from sheep and goat enterprises to cattle, with the expectation that predation will be less.

1.2 Problem statement

Predation in South Africa is an old problem, affecting producers in both the small and large livestock sectors and causing the loss of large numbers of livestock annually. A number of studies have focused on the cost of predation, specifically the direct cost of predation. Few studies have looked at the different methods to help farmers to minimise or eliminate losses due to predation. Therefore, there is a need for a study to focus on the methods used to reduce predation in South Africa. As stated previously, some farmers may change from sheep and goat enterprises to cattle farming with the expectation that predation will be less. Presently there is no information available to justify such an assumption.

Various studies have been done in South Africa on predation, but the focus was mainly on the small livestock industry. Van Niekerk (2010) came to the conclusion that losses in the small livestock industries of South Africa are high (ZAR 1 390 453 062). According to Strauss (2009) predation constituted 72% of the total annual financial losses, diseases 2%, metabolic disorders or accidents 20% and stock theft only 6% in a study at Glen in the Free State province of South Africa.

Van Niekerk (2010) also explored the impact of different techniques for the prevention of predation in the small livestock industries in South Africa and found that the factors affecting the occurrence of predation are different from the factors affecting the level of predation.

No comparable research has been done on the impact of predation on the cattle sector in South Africa and specifically the impact of techniques for preventing predation losses. There is no available published evidence that livestock losses will be limited by switching to cattle farming in South Africa, nor is there any information available on the best management practices to reduce predation on cattle farming.

1.3 Goal and objectives

The goal of this study was to provide information on the impact of predation on cattle in South Africa. This was done by quantifying the losses ascribed to predation and by identifying the best management practices for establishing meaningful and practical ways to reduce the effects of predation on cattle in South Africa.

This report is part of a larger study that included seven of the nine provinces in South Africa. The North West province was explored in greater detail in this report (dissertation) and data for the other six provinces are presented in **appendices**.

The goal of the study was pursued through the following three objectives:

Objective 1: To quantify the direct and indirect losses of predation in order to determine the impact of predation on the cattle industry in the North West province.

Typically the historical studies have only focused on the direct costs of predation. However, this study will follow the guidelines set by Strauss (2009) and also include the indirect costs to calculate the total cost of predation. The direct cost of predation was calculated from the physical losses of cattle in the North West province and the indirect costs include all the costs incurred to prevent predation, as well as the additional costs of the replacement animals. Despite the inherent difficulties associated with this type of study, Strauss (2009) have succeeded to quantify the indirect costs of predation.

Objective 2: To investigate the underlying structures in the predation prevention practices used by farmers in the North West province to improve the understanding of the current behaviour of the farmers in preventing predation.

A factor analysis (FA) was used to determine the underlying structures in the predation prevention practices and to group the management structures currently being used by farmers in the North West province. These underlying factors could then be used to explain complex events or trends in the management of predation in the North West province.

Objective 3: To investigate the factors that influence predation in the North West province, in order to identify prevention methods that result in reduced predation. Such information may contribute to the identification of best management practices for predation prevention.

Predation is divided into those factors that first affect the occurrence of predation, followed by the factors that are associated with lower levels of predation after predation has occurred. A principal component regression (PCR) that forms part of the Principal Component Analysis (PCA) was done to eliminate the chance of multi co-linearity problems and to increase the degree of freedom. After a principal component regression has been done a Pairwise Granger Causality test (Granger, 1969) was done to determine whether one time series is useful in forecasting the other. If there were factors found to be significant in both the principal component regression and the Granger Causality test, it would be possible to determine if these factors are positively or negatively correlated with predation.

1.4 Report structure

This study report consists of five chapters. Some background on predation and the impact of predation in the world are discussed in the first part of Chapter 2. This is followed by the description of the predators that cause problems for South African cattle farmers. The latter part of Chapter 2 describes the different costs of predation and also the different control methods. The research area is discussed in the first part of Chapter 3, followed by a description of the development of the questionnaire. The rest of Chapter 3 identifies the models that were used to analyse the data that were recorded. The results and the discussion are presented in Chapter 4. Finally, the conclusions which were drawn and some recommendations are presented in Chapter 5.

Note

In addition to the detailed reporting on the North West provinces, data for six provinces (Eastern Cape, Free State, KwaZulu-Natal, Limpopo, Mpumalanga & Northern Cape) are provided in **annexures B to G**.

Chapter 2
Literature review

This chapter focuses on the implications that predators have for farmers and their livestock across the globe, more particularly, losses incurred as result of predation by black-backed jackal (*Canis mesomelas*), caracal (*Caracal caracal*), hyaena (*Crocuta crocuta*), cheetah (*Acinonyx jubatus*), dogs (*Canis familiaris*) and leopard (*Panthera pardus*) on cattle. The black-backed jackal and the caracal are widely known for their impact on the small livestock sector, but it is alleged that they are also becoming a problem for cattle farmers. Furthermore, factors affecting predation and assessing the monetary value of the losses caused play an important role in accurately evaluating the problem of predation in South Africa.

2.1 Predation

Predation can be defined as a biological interaction where a predator (an organism that is hunting) feeds on its prey (the organism that is attacked) (Begon, Townsend & Harper, 1996). Predation on livestock is a problem for livestock farmers and producers in many parts of the world. Carnivores are usually opportunistic feeders that utilise alternative prey resources, including small and large domesticated livestock when survival requires it.

Farmers, however, do not always know the causes of livestock deaths (Department of Agriculture, Forestry and Fisheries of Queensland, 2013). It is often difficult to determine the causes of livestock losses, because farmers rarely know the difference between an animal that was killed or only scavenged following a natural death. Being able to determine definitively whether predation has occurred versus scavenging is important in monitoring and ultimately controlling predator problems on livestock operations. Scavenging refers to a carnivore and/or herbivore feeding on dead and decaying organic matter present in its habitat (Getz, 2011). For example, when a farmer finds cattle that have died of causes other than predation, he may find tracks, faeces and hair of predators, but it does not mean that predators were the cause of death. If the farmer was unable to tell the cause of death, it is likely that he will jump to the conclusion that predation had occurred and start hunting predators that is non-problem causing animals. In addition, the farmer does not know what was the cause of death he will not know how to solve the problem. It is also important to find the dead animal as soon as possible, because the more time that passes after an attack, the more difficult it becomes to determine the cause of death, and the more farmers speculate regarding the possible causes. In cases where farmers cannot determine the cause of deaths, the herdsmen should observe the behaviour of the livestock and look for changes. If the behaviour changes from being calm to alert and defensive, they should know that predation is the more likely alternative. Another sign that must be observed is bite marks on the livestock. If the predator is smaller than their prey there will be many bite punctures and bleeding on the prey animals (Parish, 2008). Likewise, young, inexperienced predators are apt to inflict multiple injuries by random attacks without killing their prey. Lastly, most predators tend to attack the head and neck of their prey (Parish, 2008). By knowing what type of predator is causing problems farmers are better able to select the best predation prevention methods.

Predation is causing losses to farmers and also to the different livestock industries. It is important that predation be identified on farms and that farmers find the best method of reducing predation losses. The quicker the detection of predation the sooner the problem can be dealt with.

2.1.1 Global predation

Carnivores cause predation on all types of livestock in different parts of the world. For example, golden jackal (*Canis aureus*) kill large and small livestock in Europe (Yom-Tov, Ashkenazi & Viner, 1995), coyote (*Canis latrans*) kill small livestock and cattle in North America (Snacks & Neale, 2002), grey wolf (*Canis lupus*) kill small livestock and cattle in Asia, (Boitani, 2000), dingo (*Canis lupus dingo*) kill small livestock and cattle in Australasia (Corbett, 1995), black-backed jackal (*Canis mesomelas*) kill small livestock in Africa (Bothma, 1971), caracal (*Caracal caracal*) also kills small livestock in Africa (Nowell & Jackson, 1996).

According to Yom-Tov et al. (1995) farmers in Israel suffers large financial losses due to predation, birth defects, diseases and theft. The extent of predation was evaluated by forming a network of informants among the ranchers of nine cattle herds in central and northern Golan, who, throughout 1993, reported any calf deaths or disappearances occurring in their herds. The size of the study was 7 471 female cattle in nine cattle herds. The study worked on a conception rate of 90%, which means that there should have been 5 080 calves born during 1993 in the nine herds. From the 90% conception rate 1.5% was subtracted for calves that died of birth defects and disease within a day after birth, and an additional 1.5% died from similar causes before the age of 7 months. About 2% of the adults disappeared from causes not related to predation (theft, etc.) and there is no reason to believe that the rate of disappearance among calves was smaller. Hence, 5% died or disappeared from causes not related to predation, making the total number of calves reaching 7 months 4 825, compared with 4 751 reported by the ranchers. The difference between the farmers' cattle numbers and the value calculated are calves lost to predation. The study then further indicated that 75.5% of jackal attacks on calves occurred during the first 2 days after birth, 31% of deaths occurred during delivery or several hours after it, 32% during the first day after delivery, and 12.5% during the second day. Thirteen percent of calf deaths occurred within 2-10 days, and 11% within 11-30 days after delivery. The study also reported that the face and tongue of calves attacked during delivery are eaten while the calf is still partly in the womb, but death is mainly caused by opening the posterior part of the calf's abdomen after delivery. In some cases the cow's vaginal area is also damaged, and several cows had to be put down because of serious wounds of this kind. The study by Yom-Tov et al. (1995) reported that the total cost of predation was ZAR 672 000 in 1993 in the Golan Heights of Israel.

There were two peak periods of predation according to Yom-Tov et al. (1995): 41% and 50% of the attacks occurred between February and April and July and September, respectively, and attack rates were 4.7% and 2.7%, respectively. These two peak periods were correlated with calving seasons. This means that predation spiked when there were small calves that made easy prey. The remainder (9% of attacks) occurred during the rest of the year. The study also found that the number of jackals increased from a density of 0.2 jackals/ km^2 to 2.5/km^2 (Frankenberg & Pevzner, 1988). This indicates that the population of predators was growing and was becoming more problematic to farmers.

Zimmermann, Walpole & Leader-Williams (2005) investigated the cattle ranchers' attitudes towards jaguars (*Panthera onca*) in Brazil. The study was conducted on 50 respondents who completed the questionnaires, most of whom were 41-50 years old and most (66%) had lived on their ranch for 20 years or longer. The ranch sizes varied greatly, but the majority (56%)

were <5000 ha in size. The study reported that most (82%) of the ranchers said that jaguars were a threat to their cattle and 40% said that they would be glad if all the jaguars were dead. Most (82%) of the respondents had suffered cattle losses to jaguars and the majority (66%) believed that jaguar attacks were becoming more common among their cattle (Zimmermann, Walpole & Leader-Williams, 2005).

The United State Department of Agriculture (2010) (USDA) conducted a study on the total losses due to predation. A random sample of producers was sampled during January 2010 to provide data for the study. The survey ensured that all cattle producers, regardless of size, had a chance to be included in the survey. The large producers were sampled more heavily than small operations in the study. The USDA (2010) collected samples from about 40 000 operators during the first half of January 2010 by mail, telephone, and face-to-face personal interviews, of which reports 78% were usable. The USDA reported that they had a total loss of 220 000 head of cattle in 2010. The majority of cattle and calves were killed (losses accounting for 53.1% and 9.9% respectively) by coyotes and dogs. The total value of the losses due to predation were $98 475 000 (ZAR 983 765 250) for 2010 in the United States. This value is only the direct cost of predation and does not include the indirect costs. The indirect costs are made up of the cost of guard animals, exclusion fencing, herding, night penning, fright tactics, livestock carcass removal, culling, frequent checks and other non-lethal methods. The predation management method that was being used the most was guarding animals at 36.9%, while fencing, frequent checking, and culling were the next most common methods of preventing losses at 32.8%, 32.1%, and 28.9% respectively. The non-lethal predator control measures cost farmers and ranchers throughout the United States about $ 188.5 million (ZAR 1 883 115 000) during 2010. This indicates that farmers are spending very large sums of money on the non-lethal management methods. The total cost of predation in the United States for 2010 was about $286 975 000 (ZAR 2 866 880 250).

Wang & Macdonald (2006) investigated livestock predation by carnivores in Jigme Singye Wangchuck National Park in Bhutan. The respondents in the study reported a total of 76 (2.3%) domestic animals killed by predators in a period of one year.

Exchange rate US$ 1 = ZAR 9.99

The farmers attributed 40 kills to leopards, 20 to tigers, 10 to dhole, 6 to bears, and the majority of the tiger kills were cows, mostly occurring in Trong and Langthel. The study then estimated the economic loss to predation per household, using the average local prices in 2002. The total loss of 76 head of livestock was valued at US$ 12 252 of which the majority were cattle losses. Tigers and leopards were held responsible for the majority of the kills valued at US$ 10 095, bears and dhole contributed US$ 2 157 of the total monetary loss. An average annual cash income was estimated for each household and indicated as US$ 250. The study reported that an average of US$ 44.72 was lost due to predation, which was approximately 17% of the annual income of a household. Therefore, this study indicates that the financial impact of losses per households is very severe.

2.2 Predation in South Africa

Farmers have been protecting their domestic animals from predators for centuries and will keep doing so as long as they want to be productive. The most well known small livestock predator in the 1900s was the black-backed jackal, which is widespread throughout the southern and eastern parts of Africa, including the majority of South Africa, (Cillie, 1997). Conflict of this sort is increasingly common due to human population growth and concomitant rises in human appropriation of natural resources (Graham et al., 2005; Treves & Karanth, 2003).

Problem animals can and do cause damage to livestock in South Africa and the outcome is that farmers are left with large financial losses. Relative to sheep and goat losses, cattle losses from predators are less common. The black-backed jackal and the caracal are the most important predators that cause losses in South Africa, and these two predators occur in most parts of Southern Africa (Skinner & Chimimba, 2005). The black-backed jackal and the caracal diet normally consists of smaller mammals, rodents and birds (Cillie, 1997), but lately they also prey on larger livestock.

Van Niekerk (2010) reported on the impact that the black-backed jackal and the caracal have on the small livestock industry of South Africa. The study found that the black-baked jackal and the caracal were the two most significant damage causing animal's problem predators in the five provinces examined. The total number of animals killed by the black-backed jackal was more than those killed by the caracal, but this was mainly attributed to lower population levels of the caracal. This study also reported that the total loss due to predation in South Africa was estimated at ZAR 1 390 453 062 per year. This shows that there is a major problem caused by predators in South Africa and that the problem may be greater if the cattle and the game predation are also calculated.

Strauss (2009) completed a study on predation on small livestock on one farm in the Free State. The study collected data over 5 years on Glen Agricultural Institute in the Free State. In this study the impact of predation on livestock and the reproductive performance of sheep are put into perspective. Strauss (2009) indicated that the productivity of ewes was negatively influenced by predation, and that the black-backed jackal specifically had a major impact on the sheep flocks in the study. The study also reported that predation contributed 72% of the total annual financial losses. The financial impact due to predation was ZAR 129 562/ year on the farm, and the total Merino and Dorper flock size shrank from 1 130 sheep to 552 sheep over a period of nine years. This indicates that if predators are not stopped in the next few years the livestock numbers may decrease even more and the whole flock may be lost.

Thorn, Green, Dalerum, Bateman & Scott (2012), who focused on predation in the North West Province of South Africa, confirmed that predation on cattle does happen and that it is becoming a cause of large financial loss. The study conducted 99 interviews with farmers in the North West Province with a combined land area of 4 134 km^2 (7% of agricultural land in the province). The study reported that 3 755 livestock and game were killed in the North West Province between 2006 and 2008. The four most frequent victims were goats (1412), sheep (1055), springbok (357) and cattle (334). The predators were jackal, caracal, leopards, brown hyena, cheetah and spotted hyena (Thorn et al., 2012). The results of the interviews attributed 41% of predation incidents to jackals, 20% to caracal, 15% to leopard, 12% to brown hyaena, 7% to cheetah, 3% to spotted hyaena and only one attack was attributed to serval (*Leptailurus serval*). These results illustrate that black-backed jackal and caracal is still the predators that contribute the most to small livestock predation in the North West Province.

The conclusion that can be drawn from these studies is that predation is a problem around the world and causes large financial losses to producers and consumers. Predation is common among small livestock, but it is also a growing problem for cattle farmers (Wang & Macdonald, 2006). Studies reported that predators are killing young calves and in some cases adult cattle. Predators are attacking cattle when they give birth and in some cases the vaginal area of the cow is damaged and that animal had to be put down. It is clear that farmers are struggling with predation and that their attitude toward predators is most hostile. It is also stated that predator numbers are increasing and that predator density has changed.

2.3 History of predator control in South Africa

Predation started when the first settlers came to South Africa. One of the first settlers to visit South Africa was Jan Van Riebeeck on 6 April 1652. Van Riebeeck's journal for 30 March 1654 indicates some of the problems he was having with his small livestock, from the steady losses of sheep on the mainland: "on account of the excessive wetness of ground caused by the river; many are carried away and devoured every day by leopards, lions and jackal" (Skead, 2011). Predators were also killed by the Khoikhoi and Africans around the time of Van Riebeeck. The Khoikhoi killed the predators because of predation on their flocks and they also ate some of the predators that they killed. Both the Khoikhoi and the Africans used the skin of the predators.

The Khoikhoi pastoral systems, going back two thousand years, were deeply influenced by the threat of predators, with often attacked the stock enclosures. The Khoikhoi managed predation by building their huts in a circle around the cattle kraal. Later they started killing predators with snares, dogs, poison and also by using guns for hunting. These methods were stopped by the Cape's Game Law Amendment Act in 1886, which also stated that the killing of jackal, hyaena, leopard and caracal must be stopped.

South Africa probably had a wider range of predators than any other country opened up to stock farming in the nineteenth century. It was also stated that predation tends to be worse during droughts, when other food sources diminished and sheep were weakened. This indicates why predation is high in South Africa, because most parts of South Africa that experience high predation are very dry. These provinces with high predation tend to kill more predators and also have better management practise than those with less predation (Thom, 1936).

Early evidence of predator management by governments was in 1898 to 1899, when the Cape government paid a reward for tails of jackals. It was estimated that over 50 000 jackals were killed for the rewards (Beinart, 1998). A few years after the government had managed predation they conducted a study and found that the jackal plague had spread, and the jackal now occurred in many parts of the Colony where they were formerly unknown.

In 1899 the South African War started and made it difficult to manage and to keep track of predation. This was especially good time for jackals in South Africa and they used the time well. With the farmers at war, the hunting of predators ceased and the livestock were left unprotected. During this time the numbers of predators steadily increased and started spreading to the rest of South Africa. After the war, farmers suffered from predators and started using management methods to keep their livestock safe. In the 1890s fencing wire became cheaper and more affordable to farmers, who started fencing their farms and build kraals for their livestock. The wire fences were not just keeping the sheep in, but also keeping the larger predators out and so reducing predation. In the late 1890s a better kind of fencing was made called vermin-proof fencing, which kept predators out of the farms, but required lots of management, because if there was a hole in the fence predators could get in. The holes were made by aardvark and other digging animals and it was forcing farmers to introduce better management systems on their farms. This was the main reason why aardvark was killed and not because farmers saw them as a predator (Beinart, 1998).

In the 1900s farmers had adapted to predator control and used many methods to prevent predation. One of the most effective methods was to reduce the population of predators. Therefore farmers targeted the lairs of jackal, especially during the main breeding season in spring, also an important lambing season, when jackals were most active as predators (Beinart, 1998). The small jackals were killed in the lair and the older jackals survived and moved to a new location. Other predator management methods will be discussed later.

2.4 Short description of South African livestock predators

The predators investigated in this study are those that cause the greatest losses to cattle in South Africa. These predators include black-baked jackal, caracal, hyaena, cheetah, dogs and leopard.

2.4.1 Black-backed jackal (*Canis mesomelas*)

The black-backed jackal is a medium-sized predator and manifests itself as an opportunistic scavenger of carrion and vegetable matter and a hunter of small mammals, insects and birds (Cillie, 1997). This species shows a preference for open woodlands and grasslands, but occurs universally in South Africa, only being absent from thick forests. The black-backed jackal has a distinctive black back, spotted with white hair, which expands at the neck and shoulders and becomes narrower at the end of the tail. The face, flanks and legs are red brown, while lips, throat and chest are white. The jackal has a very thick black tail and the female has 6-8 teats (Loveridge & Nel, 2008). It stands 36-48 cm high at the shoulder and it is 45-90 cm from the nose to the tip of the tail. The average weight is 7-14 kg and jackal in southern Africa is usually larger than those in the north (Macdonald, 1992).

Black-backed jackal form pairs and mate for life. The male jackal and his partner will stay in the same area till one dies and then the other one takes a new mate (De Waal, 2009). The black-backed jackal is usually nocturnal predators, but they also hunt during the day, especially when the food source is being kraaled at night. These easier prey types may set a lifetime habit which cannot be changed easily (De Waal, 2009). However, at some point animals may be introduced to predation on sheep, lambs, goats and cattle (Rowe-Rowe, 1983). The black-backed jackal's biggest enemy is the lion and farmers. Black-backed jackals can hunt in packs as big as 8-10 individuals (Macdonald, 1992). The gestation period of a black-backed jackal is two months (60-65 days), before giving birth to 1-6 pups. At the age of three months they are weaned and at eight months the young jackals find their own territories, where they can live up to 14 years in a safe area. Sometimes a young jackal may stay with the parents for a year and help raising a next litter of siblings (Loveridge & Nel, 2008).

Recently, more and more farmers have claimed that predator numbers are increasing. As with other predators, the black-backed jackal females now carry foetuses at a younger age and the litter size of six to seven foetuses has become common. In many areas, farmers claim that the situation is now worse than ever (De Waal & Avenant, 2008).

2.4.2 Caracal (*Caracal caracal*)

The caracal lives in dry, hot areas where there are many hills and shelter. The caracal is considered one of the most beautiful wild cats in the world, and can be recognized by the reddish brown coat and the black hair at the tip of the ears and the thick tail. There are also white spots on the throat, chin and stomach. The hind legs of the caracal are much longer than the front legs. The caracal is a medium sized cat, bigger than the wildcat, but smaller than the leopard. The caracal stands 40-45 cm at the shoulder and weighs 7-15.9 kg (Sunquist & Sunquist, 2002). A caracal can kill an animal twice its size by biting it in the neck and holding on till the animal suffocates. A male caracal can walk up to 95 km to mark his territory, but the female does not go far from her birth place (De Graaf, 1987). Caracals can live for a long time without water, because they get most of their water from eating their prey. According to forecasts there are 50 000 mature caracal in South Africa (Nowell & Jackson, 1996).

The caracal is sexually mature after about 20 months and mating may take place at any time of the year, but is mainly in the winter months, May and June. Mating usually takes place over a period of six days and the gestation period is about two months. They give birth to 2-3 kittens, to a maximum of 5 kittens. The female carries her young almost daily to a new safe place to prevent other predators finding the young and killing them. The young are born blind and their eyes open after a week and they begin to eat meat at approximately 45 days old. They can reach independence at 9-12 months. This means that the caracal starts its hunting experience in July and August. The life expectancy of caracals is 15 years (Wozencraft, 2005).

The caracal is a typical cat and the territory of a male caracal overlaps with the territories of several neighbouring females (De Waal, 2009). In addition to patrolling and keeping individuals of the same sex out of their territories, both sexes are also very familiar with the natural food sources in their respective territories. The individuals of both sexes are rarely seen together, except when mating or in the case of a female with larger kittens. The caracal is a very successful hunter of small mammals and birds, and it will not readily take carrion except that it may return to a carcass that it recently killed. Before they settle as young adults in territories of their own, the young cats have to keep out of harm’s way by avoiding resident territorial adults of both sexes. It is suspected that during this stressful period in their lives young cats may also kill easy prey, which could include small livestock and cattle (Nowell & Jackson, 1996).

2.4.3 Hyaena (*Crocuta crocuta*)

The spotted hyaena is also known as the laughing hyaena or the tiger wolf (Funk, 2010). The species may have originated in Asia, but it occurs mostly in the savannahs, forest edges, sub-deserts, grasslands, woodlands and mountains of Africa. It is listed as a species of Least Concern by the IUCN on account of its widespread range and large numbers estimated between 27 000 and 47 000 individuals (Hönor, Holekamp & Mills, 2008). The hyaena has a bear – like physique, rounded ears, few nipples and the presence of a pseudo-penis in the female. It is the only mammalian species in the world in which the female lacks an external vaginal opening (Glickman, Cunha, Drea, Conley & Place, 2006). The female hyaena provides only for their own cubs and do not assist other females, and the males display no paternal care. The female hyaena is larger than the male and the females dominate the males. The hyaena is also an efficient hunter and a scavenger with the capacity to eat and digest skin, bone and other animal waste. The hyaena primarily preys upon cattle, sheep, goats and donkeys (Mills & Hofer, 1998).

The spotted hyaena is a social animal that lives in large communities called “clans”, which can consist of up to 80 individuals (Szykman, Van Horn, Engh, Boyston & Holekamp, 2007). The territory size is highly variable, ranging from less than 40 km^2 to 1 000 km^2. It is a non-seasonal breeder and has an average gestation period of 110 days. The lactating female can carry between 3-5 kg of milk in their udders (Macdonald, 1992). The cubs are weaned at an age of 16 months and the average lifespan in zoos is 12 years, with a maximum of 25 years.

2.4.4 Cheetah *(Acinonyx jubatus*)

The cheetah is recognized by the round black spots on its skin and tail. There are no spots on its underside. The cheetah is the only cat with a black tear line running down from its eyes. The cheetah is the fastest animal on land and can reach speeds up to 120 km/h over a maximum distance of 500 m (Kruszelnicki, 1999). The cheetah has a deep chest to facilitate the large lungs and its waist is narrow. The adult cheetah weighs 35-70 kg and stands 66-94 cm tall at the shoulder. The female cheetah reaches maturity at 20-24 months and the males at around 20 months. The female gives birth to 5-9 cubs after a gestation period of 90-98 days. The cubs weigh 150-300 g at birth and are weaned at 12-13 months. The territory of the male is between 37-160 km^2 depending on the availability of resources in the area. The males mark their territory by urinating on conspicuous objects. Females do not establish territories (Estes, 1991).

The cheetah is a carnivore, eating mostly mammals under 40 kg. The young of larger mammals, such as wildebeests and zebras are taken at times, and adults may be taken when cheetahs hunt in groups (O'Brien, Wildt & Bush, 1986). Cheetah also kills cattle in some parts of South Africa, but unlike the jackal and caracal, legislation prevents farmers from killing cheetahs.

2.4.5 Dogs (*Canis familiaris*)

The domestic dog is a subspecies of the gray wolf and is also a predator and scavenger (Dewey & Bhagat, 2002). It has powerful muscles, fused wrist bones, a cardiovascular system that supports both sprinting and endurance and teeth for catching and tearing. Dogs hunt in packs when they kill a large animal, but this has become a rare sight in South Africa. Domestic dogs tend to injure more animals than they kill, and in most cases the farmers' own dogs or the dogs of the farmers' workers attack and kill livestock.

Dogs are sexually mature at the age of 6-12 months for both sexes. The gestation period is between 56-72 days and the average litter size is between 4-8 pups (Dewey & Bhagat, 2002).

2.4.6 Leopard (*Panthera pardus*)

The leopard can reach speeds up to 58 km/h, which is less than half the speed of the cheetah. It has an unequalled ability to climb trees even when carrying a heavy prey carcass, and also has a remarkable ability for stealth. The ability to carry a heavy carcass up a tree helps the leopard to protect its kill from bigger predators like the lion. Leopards are agile and powerful predators and they are able to take down large prey. It is an opportunistic hunter and will kill anything from beetles to a 900 kg eland from sunset to sunrise. The shoulder height of the leopard is between 45-80 cm and they weigh 30-91 kg (Nowell & Jackson, 1996).

The gestation period is from 90-105 days and the female will give birth to 2-4 cubs. The cubs will stay with the mother for 18-24 months before they become independent. The area of their territory is up to 78 km^2. In a safe environment they can live up to 21 years (Hemmer, 1976).

2.5 Valuing losses due to predation

It is important for any livestock farmer to know what the value of his livestock losses is. The livestock losses are made up of losses due to predation and also to other causes such as diseases and theft. Losses can be calculated in monetary or physical units. The conceptual models underlying economic analyses include three major components: people, products and resources (Mcinerney, 1987). It is people who want certain products and make decisions; products are goods and services that satisfy people's wants; and resources are the physical factors and services that form the basis for generating the products, and form the starting point of economic activity (Otte & Chilonda, 2001). Predation represents a negative input in the process of converting resources or production factors into products, goods and services available to people. Predation also causes direct and indirect economic losses for the producer and potential losses of value in the view of the consumer.

It can be assumed that cattle farmers aim to minimise losses due to predators each year. The cost of predation is more than just the value of the animal that has been killed. Farmers also should take into account the cost of extra input such as: control costs, prevention costs, extra labour, damaged fences, weight losses of cattle, calf abortions, genetic pool losses and injuries to cattle, which can be in some cases more than the mortality costs.

There are several ways of valuing the cost of livestock mortality; one approach is to use the output loss, the loss as "finished products" or the value of the animal when it is lost (Mcinerney, 1987; Moberly, 2002). According to Otte & Chilonda (2001) and Mcinerney, Howe & Scheepers (1992) this value is difficult to estimate if the animal is not at point of sale, in contrast to the situation when a “finished product” is lost. The losses are determined as,

$$C = L + E, \qquad [1]$$

where C is total cost, L is the loss of the animal, and E is the direct and indirect expenditure cost and control expenditure. This estimates the total cost to farmers based on the market price of an animal multiplied by the number of losses.

A second technique of valuing the cost of livestock mortality is simply to use the market value of the animal at the point of death. For example, if the animal that died was a calf and was not yet weaned, the value of the calf would be determined by the price farmers pay when they buy young calves and raise them. This value of a calf would not be very high, because the seller did not yet have high expenses, but the buyer will have high input costs to get the calf to point of sale. If the animal was weaned it will be sold according to weight to feedlots and if the animal is in production it will be sold according to market prises. This is probably the easiest way to determine the value of the animal that died.

2.5.1 Indirect cost of predation

The indirect costs of predation can be described as: the total cost of predation management and of replacement animals on the farm. The indirect costs include: additional replacement animals, extra labour, fencing, guarding animals, etc. The indirect costs are difficult to assess and vary considerably, depending on producer tolerance for loss, effectiveness (including cost-effectiveness) of methods to reduce predation problems, and suitability of operations to adjust production (Bodenchuk, Mason & Williams, 2000). Despite the difficulties in quantifying the indirect costs of predation, several authors have attempted it. Jahnke, Philips, Anderson & Mcdonald (1987) estimated that the costs of replacing animals and other indirect expenses were 162% of the costs for direct predation management activities.

Littauer, White & Hall (1986) reported that producers implemented indirect costs for predation management in New Mexico, including contributions to a cooperative predation management effort, which averaged US$ 1 468/producer. Littauer et al. (1986) also estimated that the indirect expenses to producers, combined with costs for direct management activities, were US$ 1.8 million per annum in 1986. The losses for that same year were valued at US$ 3.5 million; accordingly, indirect cost contributions to predation management activities were 34% of the total cost to the livestock industry. This indicates that producers should focus on the direct and the indirect costs of predation management if they want to minimise losses. The direct cost of predation is the cost of the animal that has died due to predation. This cost can be valued by different methods. One method is to use the market value of the animal that has died and the second method is to use a standardised value for an animal.

2.6 Predator management

Due to the large losses of livestock, after many years, farmers started calling predator ‘pests’. The concept of a pest is difficult to define and the issues involved in deciding whether an animal can be termed a ‘pest’ are both scientific and social (Hone, 1994; Moberly, 2002). One definition of a pest is: a species that conflicts with human interests, having implications for economic systems or human health (Hone, 1994; Moberly, 2002). The term ‘pest control’ refers to the regulation or management of a species defined as a pest, usually because it is perceived to be detrimental to a person’s health, to the ecology or to the economy (Bowerman & Brooks, 1971).

The public support for lethal predator control has decreased over time (Treves & Naughton-Treves, 2005), and although disagreements about predator control are unlikely ever to disappear, it may be time to cast the predator control debate in a new light. Consideration of the cost-benefit analyses may be advantageous when taking into account what type of predator control programme to use (Jeffrey et al., 1984). On the other hand, economic theory suggests that the conversion of agricultural land to development will occur if the present value of the stream of net returns from agriculture is less than the net returns from development (Irwin, Bell & Geoghegan, 2003). Thus, policy makers must understand how predator management programmes contribute to the long term net returns of agricultural production to assess the effect of these programmes on land protection.

Guarding livestock has been the natural response to predation losses since the beginning of domestication of livestock. Predation management can be divided into two management groups that can be used by farmers: lethal- and non-lethal control. These methods can further be divided into smaller groups for example: technical measures, repellents, herd management, guarding animals and physiological measures, are all types of non-lethal methods of controlling predation. On the other hand we have hunting with rifles, poisoning, trapping and hunting with dogs, which are all examples of lethal control methods. All lethal and non-lethal methods will be described and discussed below.

2.7 Predation management methods

The first predation control methods were carried out by the Khoikhoi, Africans and settlers in order to protect their flocks. Control methods are still being used today worldwide, but the difference is that the legislation now protects some predators and farmers are losing more money. The traditional way to deal with conflict between humans and predators was to attempt to exterminate the predators. This was attempted through the shooting and poisoning of predators, but has never been successful and can only reduce predation in the short run. Farmers need to find solutions to reduce predation in the long run. Some farmers in the world have learned the hard way that predators are very smart animals and they have the ability to learn from their mistakes. If farmers use any method (lethal or non-lethal) for too long, then predators soon adapt and that specific method is no longer effective.

It is clear that there are many methods that farmers use to control predation but, it is not clear which of the methods have the best results. The removal of culprit individuals from a canid population may be more efficient than attempting population control (Conner, Jaeger, Weller, McCullough, 1998; Blejwas, Sacks, Jaeger & McCullough, 2002). This means that if farmers remove the culprit individual from the farm it may prevent a “vacuum” effect of new predators moving in. The “vacuum” effect occurs when predators are removed from their established home range, which then creates a void for other predators that have home ranges that overlap with the animals that have been removed. The territory is then empty, which allows other predators to expand their range, as well as creating openings for transient predators to establish a new home range (Snow, 2006).

2.7.1 Non-lethal management methods

Non-lethal predation controls are all the prevention methods that do not include killing the predators. There are many methods available to control predation, but very little information exists on which methods are effective. However, these non-lethal preventive measures do not give permanent relief from damage, but can reduce predation. Non-lethal methods such as cage traps are effective and not harmful to non-target animals. For example, if a bat-eared fox (*Otocyon megalotis*) is caught in the cage trap, the farmer can decide if it is harmful or not and then release it unharmed. These methods are usually expensive with no guarantee that the chosen method will work effectively (Moberly, 2002; Arnold, 2001; Van Deventer, 2008; De Waal, 2009). The problem with non-lethal control methods is that some farmers don't fully understand how they work and the method is labour intensive. The non-lethal prevention methods include: fencing, livestock guarded animals, herdsmen, management and cage traps.

2.7.1.1 Fencing

Snow (2006) stated that fencing can be divided into two groups: electric and jackal-proof fencing. Although expensive, this is a long term solution, but it is labour intensive. Predator-proof enclosures will protect animals all the time, providing there is no predator within the enclosed area and that the fences are checked every day to ensure that no predators have entered. Jackal-proof and electric fences are a huge capital investment, but if they are managed properly they can protect livestock for many years. These fences keep medium-sized predators out and keep the livestock in. The downside of these methods is the frequent blocking of all possible entries for the predators. For these methods to be efficient the fence must be well maintained, because if there is an open gate or holes in or under the fence, the best fence becomes ineffective. The animals that have the greatest impact on these methods are porcupines and warthog, because they can easily dig holes under the fences. This means that the fences must be checked daily. The regular checking of fences increases expenses and consumes extra time, but it must be remembered that the advantages of fencing in the long term make it much cheaper than potential continued losses. The disadvantages of fencing are that the labour costs are increasing and that the initial capital cost is very expensive in the short term (Snow, 2006).

2.7.1.2 Livestock guarding animals

Snow (2006) reported that several forms of livestock guarding animals have been tried over time with varying degrees of success. Livestock guarding animals include donkeys, zebras, ostriches and Anatolian dogs. The use of Anatolian dogs has become popular over the last decade because of their efficiency. Some have proclaimed it as the solution to reduce predation problems, thereby eliminating the need for various lethal control techniques (Jeffrey, Green, Roger, Woodruff, Todd & Tueller, 1984).

A good livestock guarding animal is usually large, independent, intelligent and gentle towards livestock, but aggressive towards predators (Knowlton, Gese & Jaeger, 1999). These dogs are placed with a flock or herd of animals from an early age and bond with them, effectively becoming part of the herd. However, Green & Woodruff (1984) stated that Anatolian dogs are not the industry-wide solution to the predator problems, because these guard dogs are not totally effective everywhere. Unfortunately, the dogs are expensive if one considers purchase price, shipping, feed, veterinary expenses, travel and damages caused by the dog (Green & Woodruff, 1980) and they do not prevent all the killings, especially where there are large predators attacking the livestock (Snow, 2006).

2.7.1.3 Herdsmen

Herders are possibly the most effective and economically feasible method of controlling predation. Humans that stay with the cattle night and day to protect them from predators are called herdsmen. These herdsmen can also carry weapons to kill predators, but in most cases the herdsmen just carry a stick and have a dog with them. The herdsmen keep the herd of cattle together, so that one doesn’t wander off alone and get killed. The herdsman must also observe the cattle and when one is ready to calve he must take that animal to the kraal or observe when she is giving birth, to ensure that predators do not attack her while she is giving birth. The disadvantage of herdsmen is that the variable costs of production will increase because it is labour intensive and labour is expensive. The advantage of herdsmen is that where they are present, losses are generally lower than in free-ranging herds (Kaczensky, 1996).

2.7.1.4 Management

McAdoo (2000) and Shivik (2004) illustrated that with good management practices a farmer can reduce predation. Management methods include a) lights, b) noise-making devices and c) keeping the animals in kraals at night. If good management practices are in place there will be less predation.

a) Lights

Flashing lights, such as a rotating beacon or strobe light, may provide temporary protection against predation. This method should only be used in the calving season or when predation is high and not for long periods. If the method is used for long periods the predators will adapt to it and it would become less effective. Combinations of frightening devices should be used at irregular intervals to provide better protection against predation. These methods work well if the farmer is using them correctly and they can reduce predation in the short run. The disadvantage is that it is costly to purchase all the different types of lights and it can only be used for short periods.

b) Noise-making devices

Noise-making devices such as propane exploders, timed tape recordings, amplifiers and radios are used to frighten predators and reduce predation. These methods only reduce predation for a short while and should not be used for long periods, as the predators will adapt to them. They should only be used in periods of high predation or in the calving season. These methods will reduce predation in the short term, if the farmer is using them correctly. The disadvantages are that it may be costly to purchase all the different gadgets and that it can only be used for short periods.

c) Kraaling

Kraaling of cattle is one of the methods that farmers in South Africa are using more frequently to prevent predation. The method allows the cattle to graze in the day and they are kept in a kraal at night to prevent predation. This method of preventing predation is labour and cost intensive, but is highly effective. For some farmers this method is not always possible to use, because of difficult terrain or because of labour shortages, but the farmers that use it have lower losses. The disadvantage of kraaling is the extra labour and also that the predators may adapt and start killing livestock in the day.

2.7.2 Lethal management methods

Lethal methods consist of hunting at night with jackal sounds and rifles, hunting with dogs during the day, using snares, killer traps, foothold traps, leg hold traps, helicopter hunting, denning and poisoning. Great success is associated with these methods; however, most of these methods are non-selective and also kill innocent animals (Moberly, 2002; Arnold, 2001; Van Deventer, 2008; De Waal, 2009).

2.7.2.1 Shooting

Shooting is perhaps one of the most widely used methods to control predators in the world. Shooting the damage-causing animals is one of the most effective ways to reduce predation on a farm and it is also very species specific, if the hunter is experienced. Shooting of predators can also be done by helicopters in the day and is mostly used to kill older more experienced predators. Hunting has been used since the early 1870s in South Africa by settlers that were protecting their livestock against predators (Beinart, 1998). This method is also used in other countries to reduce predation on livestock (Goldberg, 1996). Aerial hunting is commonly used by agriculture agencies in the USA (Wagner, & Conover, 1999); whereas in Australia and the United Kingdom (UK) shooting is frequently used to reduce fox populations (Gentle, 2006; Moberly, 2002). This method is mostly done at night with the help of a spotlight and radio equipment. De Waal (2009) stated that shooting at night can be very selective and solve problems within a short timeframe if the farmer is experienced, but it may unintentionally cause a “vacuum” effect. Hunting can be divided into two categories: hunting carried out by the farmer himself and hunting that is done by professional hunters that charge a fee. The disadvantage of professional hunters is that they are quite expensive.

2.7.2.2 Sport hunting

Hunting predators for sport remains a traditional pastime for hunters. It may include hunting with firearms, bows or crossbows, or hunting with packs of dogs (Sillero-Zubiri & Switzer, 2004). From a farmer's perspective, sport hunting can be used to offset livestock losses or to kill problem animals. For example, hunters who hunt cheetah, jackal, etc. for their skins may also have a negative effect for the farmer, because if the sport hunters kill a predator that is not killing livestock the "vacuum" effect may be negative towards predation.

2.7.2.3 Poison baiting

Poisoning is another method to reduce problem-causing animals on farms. Baits containing poison are often used in schemes to eradicate predators from a large area. Poisoned bait is used all around the world to reduce predator numbers (Snow, 2006). In Australia, the red fox (*Vulpes vulpes*) represents a continuing threat to livestock farmers. These problems are however, managed by setting ground-level baits impregnated with poison, such as the compound sodium monofluoroacetate. The effectiveness of control programmes lies in a proper management programme to achieve long term goals.

The most common poisons that are used in South Africa are sodium cyanide, strychnine and sodium monofluoroacetate. These poisons have been used by farmers to poison bait carcasses to kill predators. This method is frequently used, because it is cheap and effective. For example, farmers often put the poison in the carcass of the animal that was killed the previous night to kill predators that return to the carcass. This method of killing predators is known as population culling. Among population culling techniques, poisoning exemplifies a necessary trade-off between cost-efficiency, target-specificity and humaneness (Sillero-Zubiri, Reynolds & Novaro, 2004). The drawback is that poison is not species specific and so you cannot target specific animals and some harmless animals die (Snow, 2006).

2.7.2.4 Trapping

Trapping is perhaps the oldest method used to reduce predator numbers in South Africa. The use of traps was first introduced by the Khoikhoi and settlers in the 1600s. Some of the traps used by farmers today include a wide variety of cage, box, leg-hold traps and snares. Some of these traps are non-lethal, because if an animal is caught in a box trap the farmer can relocate the predator instead of killing it, but other traps are not target specific and lethal. This is the reason why traps have been made illegal in many parts of the world, due to the stress, pain and suffering of the animals and the fact that harmless animals may die.

Trapping is one of the methods most frequently used to reduce predation on farms. It is very important that foothold traps or jaw-traps are correctly sited and set to be effective. Steel-jawed foothold traps without padding between the jaws are mostly used in South Africa, but cause severe injury to the animals. For this reason it is very important to check all traps at least every day to prevent unnecessary suffering, which is inhumane. It is also important that traps should never be set in paths, but should be set on the side where the problem animal should be attracted by a scent or bait. The frequent checking of traps and need for skill is the reason trapping is labour intensive and expensive (Snow, 2006).

In certain areas cage traps are usually preferred, since non-target animals can be released easily. Trapping is very cost effective and it will help farmers with predation. The disadvantages of trapping are the need to acquire difficult skills, it is time consuming, not target specific and can be inhumane (Snow, 2006; Conover, 2002).

2.7.2.5 Hunting with dogs

Hunting predators with dogs is a safe and effective way to kill predators, but if not used correctly it may cause a “vacuum” effect. Hunt clubs used dog packs very effectively in the 1960s to 1980s. It must be stressed that dog packs are only as effective as their management (Snow, 2006). A poorly managed dog pack may be a recipe for disaster (Snow, 2006). Managing predation with a pack of dogs is one of the most efficient ways of killing problem animals, but must be used when there is a fresh kill. If dog packs are used when there was not a fresh kill, they may kill predators that do not cause damage. Consequently, there may open a gap for new predators that can cause problems (Snow, 2006). Moreover, the smaller the pack of dogs, the bigger the likelihood for success, because with large packs there will be less control (Snow, 2006).Another advantage of hunting with dogs is the fact that it is a quick and effective way of targeting specific animals. However, when hunting dogs are used, poison or traps cannot be used, because the dogs may get poisoned themselves. The disadvantages of hunting with dogs are the costs of feed, veterinary, attention and training. Also, it is likely that the workers will use the dogs for hunting of non-target animals.

It is, however, important to note that not all the predators are problem animals. Management controls should aim to kill the problem animals and not all predators. Control efforts must be as target selective and as specific as possible, because bad trapping techniques, use of poison and other control methods can lead to trap shyness and bait aversion (Snow, 2006).

2.7.3 Organisations that prevent predation

Du Plessis (2013) reviewed most of the available literature on predation and related activities in South Africa. It is evident that the fragmented and often isolated way that research has been conducted calls for a very different approach to provide meaningful scientific information that can inform the development of strategies to deal effectively with human-wildlife conflict in South Africa.

For a long time activities or strategies in South Africa focused on ways to locally exterminate problem species (Stadler 2006). The Ceres hunting club is one of the predation controlling organisations that were operating in the mid-1970s to the mid-1980s (Conradie 2012). It is not clear from the club’s records what the relationship between it and organised agriculture was, but its daily records of livestock losses and predator control efforts have survived.

The bounty system was open to many abuses. Therefore, large parts of government subsidies were shifted towards the fencing of properties (jackal proof fences) in declared problem areas (specifically in the Free State Province, South Africa), while formal hunting clubs were formed to facilitate the control of “declared problem predators” on a regional level (Ferreira 1988). The hunting clubs were financed from subsidies by government and membership from livestock farmers, and were specifically active in the old provinces of the Orange Free State and Cape of Good Hope. Until 1965, hunting was conducted by more than 34 small private hunting associations in the Free State Province (Ferreira 1988). On 24 December 1965 these hunting associations were dissolved by Provincial Proclamation and a single hunting organization (Oranjejag) was created. It operated with government subsidies and compulsory membership by livestock farmers. According to Ferreira (1988) Oranjejag employed 20 full time hunters with about 1 000 hounds at its peak. Membership was at first compulsory for all farmers, but from 1971 this was changed and membership was voluntary. Consequently, membership numbers dropped sharply (from 15 904 in 1970 to 5 200 in 1973) because farmers believed that predation problems were not controlled effectively (Ferreira 1988).

The hunting associations or clubs were primarily involved with the control of black-backed jackal, caracal and vagrant dogs *C. familiaris* (Ferreira 1988; Gunter 2008). At the same time the provincial government in the Cape Province was also involved in problem animal strategies in some areas through research and method development at the Vrolijkheid Problem Animal Control Station near McGregor (currently in the Western Cape Province) and two satellite facilities at Adelaide (currently in the Eastern Cape Province) and Hartswater (currently in the Northern Cape Province). Farmers were also trained on different aspects of HPCM (Stadler 2006; Gunter 2008). According to Gunter (2008) hunting hounds were bred and trained by government officials at Vrolijkheid before being provided to the hunting clubs; the hounds men, mounted on horseback, were also trained at Vrolijkheid. The close cooperation between government officials and farmers was demonstrated by the fact that hunting clubs were inspected regularly to ensure compliance with its obligations to the state and being eligible for subsidies (Gunter 2008).

The responsibility of problem animal control in South Africa has shifted from the mid 1990's towards private landowners. Subsidized hunting clubs were phased out, dedicated research facilities have been closed down, and management today is conducted mainly by landowners, private hunting clubs and professional problem-animal hunters (Beinart 1998; Stadler 2006; Avenant & Du Plessis 2008). In an attempt by livestock farmers and wildlife ranchers to seek unified solutions for predator management in South Africa, the parties launched the Forum for Damage Causing Animals on 2 July 2009 in Port Elizabeth (De Waal 2009). The name was later changed to the Predation Management Forum of South Africa (PMF). The PMF comprises the Red Meat Producers Organisation (RPO), the National Wool Growers' Association (NWGA), the South African Mohair Growers' Association (SAMGA) and Wildlife Ranching South Africa (WRSA) as the key role players at national and provincial level. However, interested parties, such as officials from the provincial and national environmental conservation authorities (DEA) and departments of agriculture (DAFF), scientists and academics are invited to PMF meetings. Although considerable progress has been made from 2009 to 2012 by the PMF towards achieving their primary goals, the initial momentum is waning (De Waal 2009, 2012). The main reason for this situation may be found in the absence of a system of co-ordinated predation management in South Africa; without such an entity the activities related to predation remain fragmented, uncoordinated and ineffective (Avenant 2012; De Waal 2012).

According to Du Plessis 92013) government involvement is currently mostly restricted to the role of formulating and administrating the regulations of HPCM (Environmental Management Biodiversity Act, 2004: Act no. 10 of 2004). Some of the most recent initiatives by government to regulate black-backed jackal and caracal management include the unsuccessful attempt in 2006 to add these two species to the threatened or protected species list (National Environmental Management Biodiversity Act: Act no. 10 of 2004). If this effort had been successful, control of these two species would have been subjected to the issuing of relevant permits by all nine provinces; it was suggested that, in addition to being logistically near to impossible to administer, such measures would severely impact the livestock farming and wildlife ranching industries in South Africa (HO de Waal, December 2012, ALPRU, University of the Free State, *pers. comm.*). The development of National Norms and Standards for the Management of Damage Causing Animals, and the development of formal agreements with relevant stakeholders on the management of damage-causing animals is still underway in drawn out process (National Environmental Management Biodiversity Act: Act no. 10 of 2004; CapeNature 2012).

2.8 Legislation protecting predators in South Africa

The Department of Environmental Affairs and Tourism published (Government Gazette, 2005) a prohibition against farmers killing large predators on their farms without authorisation by the provincial conservation. The following animals were classified as large predators: cheetah, brown hyaena, spotted hyaena, wild dog, lion and leopard. Permits for the capture or destruction of large predators causing damage to property or which is a threat to human life will only be issued after the provincial conservation authority, in whose area of jurisdiction the action falls, is satisfied that the capture or killing of the animal is warranted. The Government Gazette (2005) also stated that damage caused by large predators is an inherent agricultural risk and therefore the onus is on the landowner to use non-lethal preventative measures to protect his property from large predators that might cause damage. These predators may not be hunted at night and dogs may not be used to kill these predators.

CapeNature initiated its permit system to manage damage-causing animals in 2009. The permits allowed night hunting of five jackals and five caracals per night. The permits had to be renewed every three months, by submission of a detailed report on the number of stock losses due to damage-causing animals. The goal of these permits was to tighten control in the management of damage-causing animals. In 2009, permits did not allow the following control methods: poison, foothold traps, public road, .22 rim fire rifle, semi-automatic weapon, bow and arrow and dogs. In 2010, the farmers in the Western Cape province demanded drastic measures to control and reduce jackal and caracal numbers, responsible for the unusually high stock losses. At the end of 2010 a short term solution was found to stop the hunting permits for a few months and in 2011 CapeNature changed the three month permits to six month permits to help farmers.

The above information was just for one province of South Africa, and if we look at the rest of South Africa we will see the following: Free State farmers do not require a permit for hunting predators on their own farms, but trained hunters need a permit to hunt on farms. The trained hunters get a permit to kill unlimited number of damage-causing animals. In Gauteng the farms obtain an exemption permit that allows the farmer to hunt damage causing-animals. If the farm is not exempted, the property owner must apply for a permit. The permit is issued based on the merits of the situation, e.g. 1 animal for the duration of 1 month. The Northern Cape farmers must apply for a permit for the culling of caracals and black-backed jackals and the permit is valid for one year, with no restriction on the number of animals that can be culled. In the North West province the owners of farms do not need permits to kill damage causing-animals. If the farmer makes use of an additional hunter, the farmer must provide written permission to the hunter to kill predators on that farm. In KwaZulu-Natal the farmers do not need a permit for hunting small predators, such as black-backed jackal and caracal, but they do need permits for hunting leopard and larger predators. In the Eastern Cape an annual damage-causing animal permit is issued with unlimited species numbers to hunt and kill in that year (CapeNature, 2011).

This shows that in some of the provinces of South Africa predator killings are regulated and monitored to prevent possible extinction. This is one of the reasons that makes data collection a problem in South Africa and may have an effect on the cost of controlling predation in some provinces.

2.9 Cost-effectiveness of predation control methods

Farmers must use cost-effective predator control strategies to keep their livestock protected. Farmers must also consider any predator control system that either reduces the costs of predator control or continues to provide effective pest control, or leads to improved conservation outcomes. The major costs of running predator control operations are extra labour, transport, and materials, and the highest of these costs is labour, which should be used only when necessary (Taylor, Rashford, Coupal & Foulke, 2009).

It is always important that farmers must first look at the economics of predation control methods. Farmers must use the benefit-cost model when attempting to determine the net benefits, gross benefits and the total cost of control methods. The benefit-cost analysis (BCA) follows the framework outlined by Engeman, Shwiff, Constantin, Stahl & Smith (2002). The BCA of predation management involves estimating the monetary value of the benefits, measured in the ZAR value of cattle saved by the reduced predation versus the costs incurred in the attempts to remove predators. Then by using the benefit-cost ratio (BCR) farmers can see if it would be profitable to use predation management on their farms. The BCR is the total value of cattle saved divided by the costs of using predation control methods. For example, if the BCR is larger than one it would be profitable to use control methods, but if the farmers want to know how much money is saved or lost using predator control methods, the net benefit (NB) model could be used. NB is calculated by taking the number of cattle saved multiplied by the value of the animals minus the costs of control methods. If the value is larger than zero the farmer gains by using control methods, but if the value is less than zero the farmer loses money. It is possible that BCR and the NB can be negative in one year and yet for the next 15 years it may be positive. For example, if the farmer uses fence line or electric fencing, the construction costs will be very high in year one, but the next 15 years there will just be small repair costs. For this reason the cost-benefit will probably be negative in year one and positive for the next few years (Engeman et al., 2002). Farmers can also use the net present value calculation for fence lines.

A second very simple economic model can be developed for the above calculation of costs (Tisdell, 2006).

$$B = a - g(E), \qquad [2]$$

where B is economic benefit, *a* is the level of economic loss in the absence of control of predation, and E represents the level of variable cost of (expenditure on) control of predation. The total cost C of control of predation can be seen as consisting of possible start-up, fixed or overhead cost, k, and variable outlays, E. Thus:

$$C = k + E, \qquad [3]$$

where $k \geq 0$. Therefore, the net benefit from predation control is:

$$NB = B - C = a - g(E) - (k + E) \qquad [4]$$

$$= f(E) - (k + E) \qquad [5]$$

If the benefit function increases at a decreasing rate, that is if $f' > 0$ and $f'' < 0$, the net benefit from predation control will be maximised where the value of E, expenditure on control, is such that the extra economic benefit from control equals extra costs of control, that is from the value of E for which:

$$f'(E) = 1 \qquad [6]$$

This is so, provided that for this value

$$F(E) - (k + E) > 0, \qquad [7]$$

That is total benefits exceed total costs. Otherwise no expenditure on controlling predation is optimal. Other things equal, the higher k is, the more likely is it that no control is optimal. However, even if k = 0, it is possible that no control of predation is optimal because the marginal benefit of control of predation, $f'(E)$, is always less than the marginal costs of control (Tisdell, 2006).

2.10 Arguments for managing of predator populations in South Africa

The losses due to predators are widely reported, as also the impact that predation has on the livestock industries of South Africa. Very little research has been done on the impact of predators on the livestock industry, especially the cattle industry of South Africa. Studies that have been done in South Africa report, that black-baked jackal and caracal are the predators that have the greatest impact on livestock.

Losses due to predation are not the only economic losses, because there are also additional costs in preventing predation and the replacement of killed animals. The financial losses due to predation are believed to be more than the theft of animals and animals which die from diseases. Van Niekerk (2010) indicated that the cost of predation by black-backed jackal and caracal was valued at ZAR 1 390 453 062 in the small livestock industry. This shows that livestock predation can jeopardise farming livelihood and agricultural production (Graham et al., 2005). Thorn et al. (2012) reported that a total of 3 755 animals were killed by predators in the North West province of South Africa in 2012. The total number (334) of cattle that were killed in that year was derived from 99 interviews on 7 % of the agricultural land in the province.

These studies indicate that there is a large problem with predation in South Africa and that predators should be dealt with. Legislation makes it difficult for farmers to protect their livestock and is also straining their budgets. New legislation should be more lenient towards the farmers and legislators should remember that the farmers keep South Africa fed and not the predators.

2.11 Implications for the research

The literature in this chapter provided the necessary knowledge to reach the goals and objectives that were set in Chapter 1. This section contributed to the knowledge on predation and provided key knowledge on aspects of predation.

This review of literature showed that predation was an old problem and that it had grown over the years. It also showed that small livestock predation is very high in South Africa, but there is very little information available on cattle predation in South Africa. Cattle predation is very common in the rest of the world, such as Australasia, Bhutan and Israel and many studies were done there. Those studies showed that cattle predation is possible and that it could be a problem in South Africa, but the extent of the problem is not yet clear. This means that it is now even more necessary to find ways to reduce predation on cattle.

The studies reported in this section showed that some methods had been successful in the reduction of predation, but these methods differ for different predators. This made it more difficult for livestock farmers, because farmers must know which predator is targeting their livestock and then use the correct control method for that specific predator. Also, legislation and nature conservation in South Africa prevents farmers from killing certain predators that are preying on their livestock, so even if the best method of reducing predation is to reduce predator numbers, it may not be allowed by law. This will make it difficult for researchers to indicate best management practices, but it would not make it impossible.

The studies of Strauss (2009) and Van Niekerk (2010) a baseline on how to calculate the direct costs of predation, but did not help with the indirect costs of predation. The studies by Littauer et al. (1986) and Jahnke et al. (1987) provided the knowledge to calculate the indirect costs of predation. Thus the calculations of direct and indirect costs will be based on these studies.

This section also helped with the construction of the questionnaire. The questions that were asked in the questionnaire were based on the results that other researchers had struggled to obtain. For example, the questionnaire did not ask the farmers for a value per animal that was lost, because some farmers are stud breeders and they would value their animals much higher than commercial farmers, which would have an effect on the final result. The different control methods that were used by farmers were also provided by the literature review. The questions on breeding months and calving months were also provided by the literature and helped to understand that there may be a correlation between the livestock calving season and predation. This may be because livestock calving season overlaps with the time when young predators start to hunt.

This section of the study also helps to understand the cost-benefit analysis better. The CBA helps farmers when they decide which methods to use when it came to protecting their cattle. The cost must never exceed the benefit that the farmer could get when they use preventing methods.

Chapter 3
Data and Methodology

3.1 Introduction

This chapter is divided into different sections. The first section focuses on the study area, questionnaire and methods of obtaining data. The second section focuses on the research methods used to analyse the factors affecting predation and also the factors affecting the level of predation on cattle farms in North West province. The third section indicates the characteristics and actions that are hypothesised to influence predation. The chapter also focuses on the research methods used to analyse the best management practices in the North West province of South Africa.

3.2 Methods of obtaining data

3.2.1 The research area

The North West province is located in the north of South Africa on the Botswana border, fringed by the Kalahari Desert in the southwest (Northern Cape Province), Gauteng province to the east, and the Free State province to the south (Figure 3.1). The North West province was established at the end of 1994, and includes parts of the former Transvaal Province and the Cape Province, as well as most of the former "Bantustan" of Bophuthatswana.

The North West province consists of flat areas of scattered trees and grassland and has a total size of 106 512 km^2. The average temperatures range from 17°C to 31°C in summer and from 3°C to 21°C in winter. It is very dry with a low annual rainfall averaging about 360 mm, and ranging from 281 mm to 1203 mm per annum (De Villiers & Mongold, 2002). It is ideal for farming with a diverse range of products that include sheep, cattle, game (wildlife), maize, sunflowers, tobacco, cotton and citrus fruit.

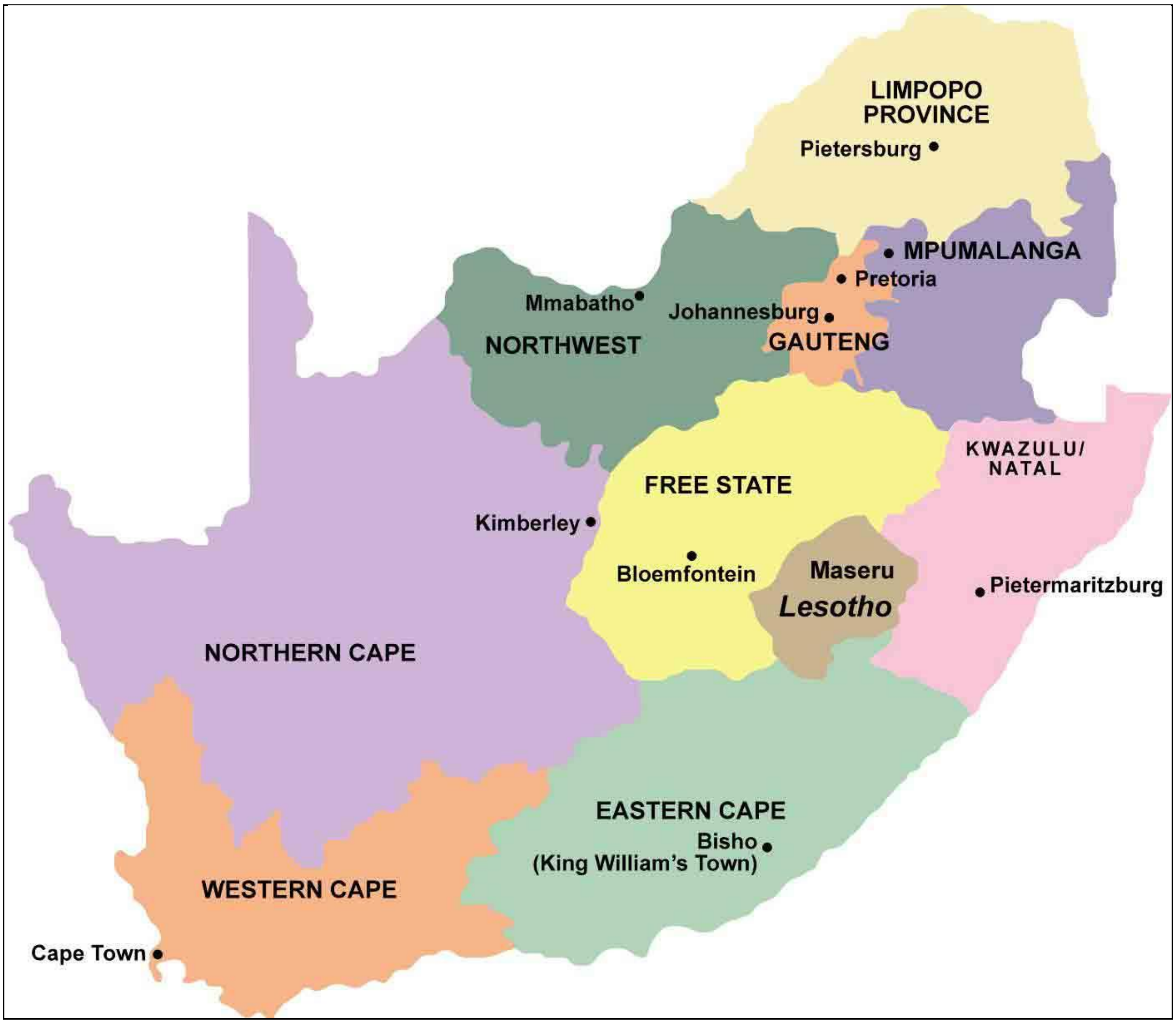

Figure 3.1 The nine provinces of South Africa.

Source: http://www.afrilux.co.za

The North West province is divided into four District Municipalities, namely Bojanala Platinum District Municipality, Ngaka Modiri Molema District Municipality, Bophirima District Municipality (Dr Ruth S Mompati) and Southern District Municipality (Dr Kenneth Kaunda).

The North West province holds the second largest number of beef cattle in South Africa, namely 1 221 538, comprising about 16% of the national cattle herd (Figure 3.2).

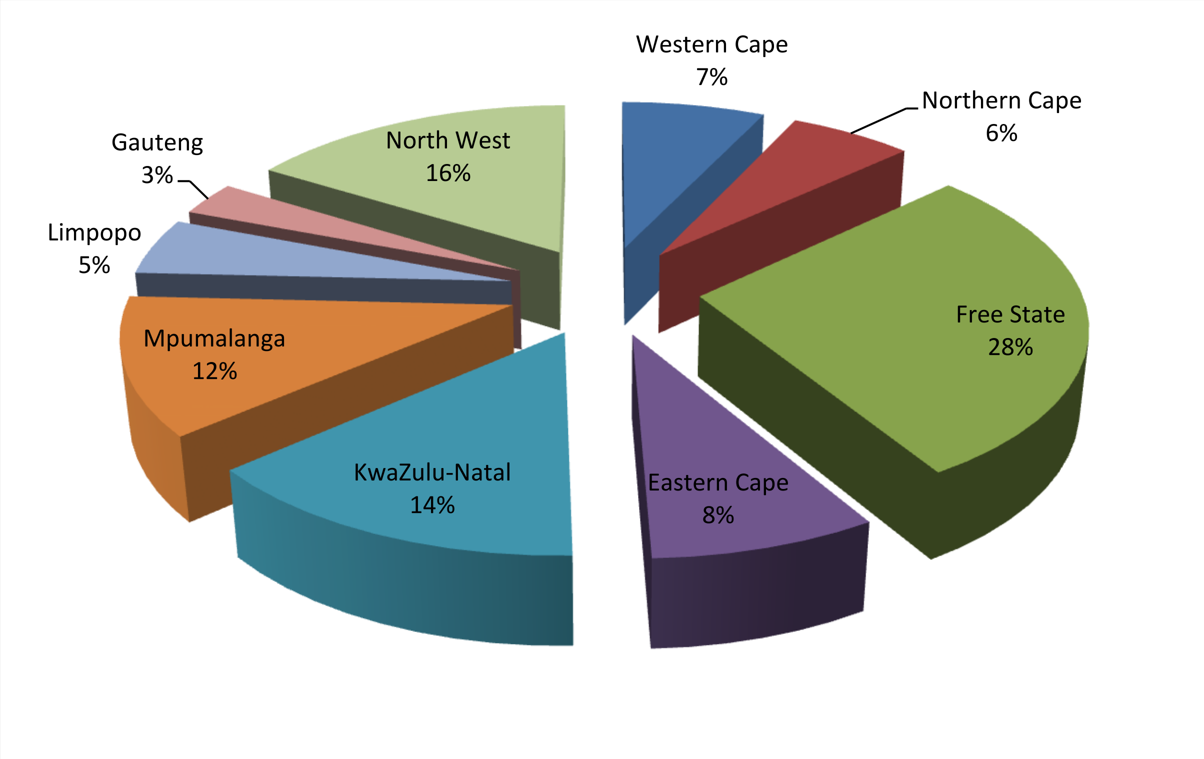

Figure 3.2 The distribution of cattle in the nine provinces of South Africa.

Source: DAFF, 2012

3.2.2 Sample specification and sample size

The survey sampling method used in this study describes the process of selecting a sample of elements from a target population in order to conduct a survey. The sample size depends largely on the degree to which the sample population approximates the characteristics and qualities present in the general population (De Vos, Strydom, Fouche & Delport, 2002). The larger the sample utilised in the survey procedure, the more accurate and closer the actual results would be to that of the entire population. The larger the population, the smaller the proportionate sample size required (Leedy, 1996). Leedy (1996) also illustrated that at a specific population size it becomes irrelevant to increase the sample size any further.

A sample becomes inaccurate mainly due to human factors and distortion due to the selection process. In the most general scenario, the components of the sample are chosen from the population by a process known as randomisation (Montshwe, 2006). The manner in which the sample units are selected is very important. This means both representation and adequacy should be taken into consideration when generalising from the sample to the larger population (i.e. the sample is used to make inferences about a larger universe). A statistically adequate sample is one that is of such size that the inferences drawn from the sample are accurate to a given level of confidence (Frick & Groenewald, 1999). Representivity means that the sample selected should have approximately the same characteristics as the population relevant to the research in question (De Vos et al., 2002). Randomisation means selecting a part of the whole population in such a way that the characteristics of each of the units of the sample approximate the broad characteristics inherent in the total population (Babbie, 2001). Lastly, it is important that the sample size should be relatively large, especially when the chi-square test is used, because it has a sampling distribution that approximates the true distribution (Gordon & Schaumberger, 1978).

The sample size of each magisterial district of this study was based on the number of cattle in each district in the North West province. Therefore, it was necessary to determine the number of cattle in each municipality. The number of cattle in the North West province was provided by the Department of Agriculture, Forestry & Fisheries (2012).

The number of cattle in each district in the North West province is shown in Table 3.1. The number of cattle owned by commercial farmers in the North West province is 1 221 538. The largest number of cattle in the North West province is in Bophirima District Municipality (444 674) and the smallest number of cattle is in Bojanala Platinum District Municipality (184 276).

Table 3.1 The number of cattle in the four district municipalities in the North West province

District municipality	Number of cattle
Bojanala Platinum District Municipality	184 276
Ngaka Modiri Molema District Municipality	253 005
Bophirima District Municipality (Dr Ruth S Mompati)	444 674
Southern District Municipality (Dr Kenneth Kaunda)	339 583
Total	**1 221 538**

Source: DAFF, 2012

Probability sampling is based on a random selection. Each sample from the population of interest has a known probability of selection under a given sampling scheme. Probability sampling consists of simple random sampling, stratified random sampling, cluster sampling and quota sampling. The stratified random sample suited the purposes of this study best, due to the fact that all the respondents are active cattle farmers (Leedy, 1996; De Vos et al., 2002). Stratified random sampling is also known as proportional random sampling. This sampling method was used because only cattle farmers were selected from the different types of farmers. A weighted average based sample of cattle farmers was selected from each district. The number of representatives was correlated with the number of cattle in the province. For example, 1 221 538 cattle for the North West province was divided by the number of cattle in South Africa (7 707 254) (only cattle in commercial enterprises). The answer (0.158) was then multiplied by the total number of representatives (1 500) and finally it yielded the answer of 238 representatives that had to be interviewed in the North West province (Table 3.2). Each province was then further divided into different magisterial districts and then also divided into the different local municipalities. The reason for dividing the province into smaller areas was to balance the distribution of farmers in the province.

Table 3.2 The sample size and estimated distribution of farmers and cattle in each province of South Africa

Province	Farmers	Cattle	Proportion of national cattle herd %	Farmers sampled per province
Western Cape	3 114	542 928	7	106
Northern Cape	4 705	509 475	6	99
Free State	6 065	2 215 042	28	430
Eastern Cape	4 640	611 242	8	119
KwaZulu-Natal	2 611	1 038 048	14	202
Mpumalanga	2 336	901 801	12	176
Limpopo	2 644	411 080	5	80
Gauteng	1 192	256 100	3	50
North West	4 135	1 221 538	16	238
Total	**31 442**	**7 707 254**	**100**	**1500**

Source: DAFF, 2012

The total sample size of 1 500 respondents was determined by the limiting budget. As stated previously, this report forms part of a larger study that was conducted in South Africa. The information in Table 3.2 illustrates the complete breakdown of the sample size for all the provinces. It shows specific number of farmers, namely 238 that had to be interviewed in the North West province.

The number of farmers to be interviewed in each municipal district in the North West province of South Africa is shown in Table 3.3.

Table 3.3 The sample size and estimated distribution of cattle and farmers in each district municipality

District municipality	Cattle	Proportion of cattle in province%	Farmers sampled per municipal district
Bojanala Platinum District Municipality	184 276	15	36
Ngaka Modiri Molema District Municipality	253 005	21	50
Bophirima District Municipality (Dr Ruth S Mompati)	444 674	36	85
Southern District Municipality (Dr Kenneth Kaunda)	339 583	28	67
Total	**1 221 538**	**100**	**238**

Source: DAFF, 2012

The total number of livestock farmers in the North West province was estimated at 4 135 with a total of 6 738 014 ha of grazing land (DAFF, 2012). Therefore, a sample size of 5.8% (238) representatives was deemed adequate for this study. The contact details of the livestock farmers were provided on a confidential basis by the provincial RPO structures. The samples of farmers were drawn randomly and they were interviewed telephonically to provide the information required for the questionnaire.

3.2.3 Development of the questionnaire

A structured questionnaire was developed to obtain relevant information from respondents. This questionnaire was designed to be used during a telephonic interview to obtain information on socio-economic factors, managerial factors, non-lethal predation control methods and lethal predation control methods. The questionnaire was designed in accordance with the principles suggested by Moberly (2002) and also in line with the questionnaire developed and used by Van Niekerk (2010). The questionnaire included questions on the education level of farmers, herd size, farm size and location, losses of livestock due to predators, type of predator control methods used, spending on prevention methods per annum and different management practices. The management questions on certain farming practices included; frequency of counting and handling the herds, calving location, pregnancy diagnoses (PD), whether the cattle are dehorned and whether the carcasses of dead animals are removed. Questions on the various control methods were included, as well as the costs of the different methods.

3.2.4 The survey

It was decided based on time and expense that a telephone survey (Tyzoon, 1979; Van Niekerk, 2010) would be conducted to collect data from the large sample size. The majority of the telephone interviews were held in the early morning and late afternoon. Although criticism is often voiced at the use of telephonic surveys, they provide the largest amount of information for the time and effort expended (Knowlton, Gese & Jaeger, 1999). A review of several studies which have compared data collected by different interview methods suggested the data are comparable (Colombotos, 1969; Coombs & Freedman, 1964; Hochstim, 1967; Klecka & Tuchfarber, 1978; Kofron, Bayton, & Bortner, 1969; Larson, 1952; Rogers, 1976; Schmiedeskamp, 1962; Sudman & Ferber, 1976; Telser, 1976; Wheatley, 1973). The response rate of telephonic interviews is between 45-95%. The telephone interviews for this study were held in June and July of 2012.

The survey was carried out for seven provinces, but this report will only provide detail for the North West province. The primary information for the six other provinces are provided in **Annexures B** to **G**.

3.3 Research methods

3.3.1 Methodology

The methodology used in this study consisted of quantification of predation losses to set a baseline of monetary economic value to predation losses in the North West province. The factors affecting predation in the province was analysed by means of regression analyses.

3.3.2 Quantification of predation losses and expenditure on predation management methods

The first objective of this study was to quantify the direct and indirect losses of cattle due to predation in the North West province. Quantification was done by determining the number of cattle that died due to predation. This was calculated by dividing the number of cattle that died by the total number of cattle. The answer described the average cattle predation in the North West province. The average was then multiplied by the number of cattle in the North West province to get an estimate of total predation in the province. The total number of cattle lost to predation was multiplied by the market price of an animal to get the total direct cost of predation. The value of an animal was estimated at ZAR 10 400 as suggested by the National Livestock Theft Forum (2012). This value was used, because it is difficult to set a price on an animal that was killed before the point of sale. This value may be an overestimation, but it provides a base line and could be changed in future analysis.

The indirect cost of predation consists of all the costs that are associated with the prevention of predation, for instance: the cost of hiring a specialist predator hunter, the farmer's own hunting costs, cost of traps (foothold and cage), hunting with dogs, poison, herdsmen, fencing (jackal proof and electric), lights, kraaling and guarding dogs. Although some of these methods are a once-off expense, maintenance is always necessary afterwards. The indirect cost per animal was calculated by adding the indirect costs of predation and dividing the result by the total number of cattle to yield the answer. The answer then represents a Rand (ZAR) value of indirect cost per animal. That value is then multiplied by the total number of cattle in the North West province to get a total estimated indirect cost for the province.

3.3.3 Identifying the underlying structure in the predation prevention practices

The second objective of the study was to explore the underlying structure in the predation management practices used by farmers in the North West province. Factor analysis was used to explore the underlying structure in the study. The factor analysis was performed to find and interpret the underlying, common factors (NCSS, 1998) of respondents regarding predation management methods. The factor analysis furthermore explains the variance in the observed variables in terms of underlying latent factors (Habing, 2003).

The following discussion is based on the work of Jordaan & Grové (2007). The first step when performing any analysis is to determine whether it is actually necessary and/or worthwhile to perform the factor analysis. This can be done by measuring the adequacy with which the different variables can be sampled.

- *Measure of Sampling Adequacy (MSA)*

Data need to be correlated to justify the use of the factor analysis. Habing (2003) stated that it doesn't make any sense to use factor analysis if the different variables are not related to each other- "why model common factors if they have nothing in common?" The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is one measure to determine whether individual variables are suitable for use in the factor analysis. The KMO measure of sampling adequacy can be presented as (Berghaus, Lombard, Gardnwe & Farver, 2005):

$$\text{MSA(J)} = \frac{\sum_{k\neq j} r_{jk}^2}{\sum_{k\neq j} r_{jk}^2 + \sum_{k\neq j} q_{jk}^2} \quad [8]$$

Where MSA(J) is the measure of sampling adequacy for the Jth variable, r_{jk}represents an element of the correlation matrix **R**, and q_{jk} represents an element of anti-image correlation matrix **Q**, which is in turn defined by the equation $\mathbf{Q} = \mathbf{SR^{-1}S}$, where S = (diag $R^{-1})^{-1/2}$ (Kaiser & Rice, cited by Berghaus et al., 2005). The MSA lies between 0 and 1 and is described by Kaiser as a measure of the extent to which a variable "belongs to the family" of the largest group of variables. A KMO-value which is lower than 0.5 is considered to be "unacceptable" (Kaiser & Rice, cited by Berghaus et al., 2005).

The next step in the factor analysis is to determine the number of factors that have to be specified in the factor analysis.

- *How many factors to include in factor analysis*

According to Habing (2003) the following rules can be applied to determine the number of factors that have to be specified in the factor analysis:

- Kaiser's criterion / Eigen Value >1 – Take as many factors as there are principal components with eigen values that are larger than 1.
- Screen Plot – Take the number of factors corresponding to the last eigen value before they start to level off.
- Fixed percentage of Variance Explained – Keep as many factors to explain 60%, 70%, 80-85%, or 95%.
- A priori – If you have a hypothesis about the number of factors that should underlie the data, then that is probably a good number to use.

In this study a principal component analysis was conducted and Kaiser's criterion was used to determine the number of factors to be included in the factor analysis. Kaiser's criterion suggests that only the number of principal components that have eigen values that are greater than one should be included in the factor analysis.

After the number of factors that have to be specified is determined, the next step is to perform the factor analysis. When performing the factor analysis one must be sure that some variables have not scored high factor loadings in more than one factor. Whenever a variable scores high factor loadings in more than one factor, the output can be rotated.

- *The need for rotation*

Rotation serves to make the output more understandable and is usually necessary to facilitate the interpretation of factors. Rotation will alter the eigen values of particular factors and will change the factor loading (Garson, 2004). If a variable has high factor loadings in more than one factor the output can be rotated. Varimax rotation maximises the sum of the squared factor loadings across the columns. This tends to force each variable to load high on as few factors as possible. Ideally it will cause each variable to load high on only one factor (Habing, 2003).

The next step is to determine the goodness of fit of the factor analysis. The goodness of fit indicates whether or not the specified factors explain a sufficient amount of the variation in the variables. The communality is the measure that indicates the amount the variation in the variables that is explained by the specified factors.

- *Communality*

The communality is the proportion of the variation of a variable that is accounted for by factors that are retained. It is the R-squared value that would be achieved if this variable were regressed on the retained factors.

Garson (2004) stated that, whenever an indicator variable has a low communality, the factor model is not working well for that indicator. He suggested that such an indicator should probably be removed from the model. A communality of 0.75, however, may seem high, but is meaningless unless the factor on which the variable is loaded is interpretable. Likewise, a communality of 0.25 may seem low, but may be meaningful if the item is contributing to a well defined factor. It is thus not the communality coefficient per se that is critical, but rather the extent to which the item plays a role in the interpretation of the factor. Garson (2004) concluded that the role is, however, often greater when the communality is high. A communality that exceeds 1.0, however, is an indication that there is a spurious solution which may reflect a too small sample size or the researcher may have too many variables (Garson, 2004).

The last step in factor analysis is to determine whether the internal consistency in each of the factors is reliable.

- *Reliability analysis scale Alpha*

Cronbach's Alpha was used to calculate the overall reliability of internal consistency (Cronbach & Meehl, cited by Lazenbatt, Thompson Cree & McMurray, 2005). This is an indication of the extent to which each item is measuring the same concept as the overall section in the questionnaire covering the personal reasons for using predation management methods. Lazenbatt et al. (2005, cited by De Vaus, 2004; Bryman & Cramer, 2005), stated that a Cronbach's Alpha value greater that 0.7 is an indication that the level of reliability is acceptable.

Cronbach's Alpha is calculated by:

$$a = \frac{K}{K-1}\left[\frac{\sum_{i=l}^{K}\sigma_{ii}}{\sum_{i=l}^{K}\sum_{j=l}^{K}\sigma_{ij}}\right] \qquad [9]$$

Where K is the number of items (questions) and σ_{ij} is the estimated covariance between items i and j. Note that σ_{ii} is the variance (not the standard deviation) of item i.

3.3.4 Identifying the factors affecting the occurrence and the level of predation

The third objective was to determine the factors that have an effect on the occurrence of predation and also the factors that have an effect on the level of predation. It is hypothesised that the variables that affect the occurrence of predation and variables that affect the level of predation differs. Van Niekerk (2010) showed that the variables that effect the occurrence of predation and variables that effect the level of predation are not the same, therefore it was hypothesised that the effect will also be the same for cattle.

In order to overcome the problem of multi co-linearity, the regression analyses were performed within a principal component regression (PCR) framework that forms part of the of the Principal Component Analysis (PCA). Two different models were used to identify the factors that have an effect on the occurrences of predation and factors that have an effect on the level of predation. Logit regression was used to identify the factors that influence the occurrence of predation and the Truncated model was used to identify the factors that influence the level of predation. The methodology is based on the method explained by Magingxa, Alemu & Van Schalkwyk (2006). PCR is applied within a maximum likelihood estimation framework.

3.3.4.1 *Factors affecting the occurrence of predation*

The correlation matrix C^2 using both standardised and non-standardised variables was used to calculate eigen values $\lambda_1, \lambda_2, \ldots \lambda_K$ and corresponding eigenvectors v_1 respectively as

$$|C - \lambda I| = 0, \; |C - \lambda_j I| \, v_j = 0 \qquad [10]$$

The eigenvectors V_j were then arranged to give matrix V in equation 11:

$$V = \begin{bmatrix} V_{11} & V_{12} \cdot & \cdot \cdot V_{1k} \\ V_{21} & V_{22} \cdot & \cdot \cdot V_{2k} \\ \cdot & \cdot \; \cdot & \\ \cdot & \cdot \; \cdot & \\ \cdot & \cdot \; \cdot & \\ V_{k1} & V_{k2} \cdot & \cdot \cdot V_{Kk} \end{bmatrix} \qquad [11]$$

The matrix V is orthogonal, as its columns satisfy the condition $v_i' v_i = 1$ and $v_j' v_i = 0$ for $i \neq j$

$$Z = X^S V \qquad [12]$$

Where X^S is $n \times k$ matrix of standardised variables and V is an eigenvector matrix as defined in Equation 12. There are k principal components as there are k variables. The new sets of variables, unlike the original variables, are orthogonal, i.e. they are uncorrelated.

After the principal components (PCs) are calculated, as PCs with the smallest eigen values are eliminated, and the following equation 13 was fitted to determine PCs having significant impact on the probability of the occurrence of predation:

$$Ln\left(\frac{P}{1-P}\right) = \alpha_0^s + X^s VV'\varphi^s + \varepsilon \qquad [13]$$

After insignificant PCs from equation 14 are identified and eliminated, equation 15 is developed in terms of the retained principal components.

$$Ln\left(\frac{P}{1-P}\right) = \beta_0^S + Z\gamma + \varepsilon^{\circ\circ} \qquad [14]$$

Where, $Z = X^S V$ and $\gamma = V'\alpha^s$. Z is a $n \times \ell$ matrix of retained principal components, V is a $k \times \ell$ matrix of the eigenvectors corresponding to the ℓ retained components; γ is $\ell \times \ell$ vector of coefficients associated with the ℓ components. Standard errors of the estimated coefficients γ are represented by $\ell \times 1$ vector.

$$Var(\hat{\gamma}) = \hat{\delta}^2 (Z'Z)^{-1} = \hat{\delta}^2\, diag(\lambda_1^{-1}, \lambda_2^{-1}, \ldots.\lambda_l^{-1}) \qquad [15]$$

Where $\hat{\delta}^2$ is the variance of residuals from equation 15. Therefore, standard error of γ may be given by

$$k^s = \left(s.e._{\hat{\gamma}_1}\, s.e._{\hat{\gamma}_2} \ldots s.e._{\hat{\gamma}_\ell}\right) \qquad [16]$$

Results obtained using equation 14 may be transformed back to the principal components estimators of standardised variables as follows:

$$\begin{bmatrix} \alpha_{1,pc}^s \\ \alpha_{2,pc}^s \\ . \\ . \\ . \\ \alpha_{k,pc}^s \end{bmatrix} = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1l} \\ V_{21} & V_{22} & \cdots & V_{2l} \\ . & . & . & \\ . & . & . & \\ . & . & . & \\ V_{k1} & V_{k2} & \cdots & V_{Kl} \end{bmatrix} \text{x} \begin{bmatrix} \hat{\gamma}_1 \\ \hat{\gamma}_2 \\ . \\ . \\ . \\ \hat{\gamma}_\ell \end{bmatrix} \qquad [17]$$

Where $\hat{\gamma}_i$ is the estimator of γ_i in equation 15. The constant $\alpha^s_{0,pc} = \bar{y}$. The standardised coefficients evaluate the relative importance of the explanatory variables in determining the occurrence of predation.

Following Fekedulegn, Colbert, Hick & Schuckers (2002), the variance of the principal component estimators as standardised variables are given by:

$$Var\left(\alpha^s{}_{pc}\right) = \Psi^s_\ell K^S \quad [18]$$

Where Ψ^s_ℓ contains the squares of the elements of V^S_l in equation 11, and K^S contains the squares of the elements of the matrix of standard errors of the coefficient matrix of γ in equation 14. The corresponding standard errors for the estimators of principal components of standardised variables are given by:

$$s.e.\left(\alpha^s_{pc}\right) = \left[Var\left(\alpha^s_{pc}\right)\right]^{1/2} \quad [19]$$

Following Fekedulegn et al. (2002), standardised coefficients $\alpha^s_{j,pc}$ of standardised variables X^x_j were transformed back to non-standardised coefficients $\alpha_{j,pc}$ of X_j

$$\alpha_{j,pc} = \frac{\alpha^s_{j,pc}}{s_{xj}}, j = 1,2, \ldots., k \quad [20]$$

and

$$\alpha_{0,pc} = \alpha^s_{0,pc} - \frac{\alpha^s_{1,pc}\bar{x}_1}{s_{x1}} - \frac{\alpha^s_{2,pc}\bar{x}_2}{s_{x2}} - \ldots - \frac{\alpha^s_{k,pc}\bar{x}_k}{s_{xk}} \quad [21]$$

Where S_{xj} is the standard deviation of the j^{th} original variable X_j, and $\alpha^s_{0,pc}, \alpha^s_{1,pc}, \alpha^s_{2,pc}, \alpha^s_{k,pc}$ are coefficients of the standardised variables.

3.3.4.2 Factors affecting the level of predation

For this section the Truncated model was built into a PCR analysis to determine the factors that affect the level of predation. The procedure essentially is the same as that described in Section 3.4.3.1 where a Logit model was built into a PCR analysis.

The independent variables were standardised as follows:

$$a_i^s = (a_i - \bar{a}_i)/s_{a_i} \qquad [22]$$

a_i^s is the i^{th} standardised independent variable under consideration, a_i is the i^{th}explanatory variable, $\bar{a}_i$ is the mean of the independent variable concerned, as s_{a_i} represents the standard deviation of the i^{th} independent variable. The standardised independent variables are required for the computation of principal components which will be used in the regression analysis. Since the methodology is conducted in a Truncated framework, the dependent variable d is not transformed to standardised dependent variable d^sbecause the Truncated only takes censored variables [0; 1]

The correlation matrix C^2 using both standardised and non-standardised variables was used to calculate eigen values $\lambda_1, \lambda_2, \ldots \lambda_K$ and corresponding eigenvectors v_1 respectively, as

$$|C - \lambda I| = 0, \; |C - \lambda_j I| \, v_j = 0 \qquad [23]$$

The eigenvectors V_j were then arranged to give matrix V in equation 24:

$$V = \begin{bmatrix} V_{11} & V_{12} \cdot & \cdot \cdot V_{1k} \\ V_{21} & V_{22} \cdot & \cdot \cdot V_{2k} \\ \cdot & \cdot \; \cdot & \\ \cdot & \cdot \; \cdot & \\ \cdot & \cdot \; \cdot & \\ V_{k1} & V_{k2} \cdot & \cdot \cdot V_{Kk} \end{bmatrix} \qquad [24]$$

The matrix V is orthogonal, as its columns satisfy the condition $v_i' v_i = 1$ and $v_j' v_i = 0$ for, $i \neq$ j

$$Z = X^S V \qquad [25]$$

Where X^S is $n \times k$ matrix of standardised variables, and V is eigenvector matrix as defined in Equation 25. There are k principal components as there are k variables. The new sets of variables, unlike the original variables, are orthogonal, i.e. they are uncorrelated. The Truncated Regression Model is as follows:

$$f(\alpha_i : \alpha_i > 0) = \frac{f(\alpha_i)}{P(\alpha_i > 0)} = \frac{\frac{1}{\sigma}\phi(\frac{\alpha_i - \beta_\alpha' z_i}{\sigma})}{\phi(\frac{\beta_\alpha' z_i}{\sigma})} \qquad [26]$$

Where values α_i are estimated by the Truncated Regression Model, and are standardised coefficients for the constant and the independent variable respectively. Since the eigenvectors are orthogonal to one another as defined by the eigenvector, matrix V where $VV' = I$, according to Fekedulegn et al. (2002) the original Equation 26 can be reformulated in the form:

$$\Psi = \beta_0^s + A^s V V' \beta^s + \varepsilon \qquad [27]$$

Or

$$\Psi = \beta_0^s + \sum p + \varepsilon \qquad [28]$$

Where $A^s V = \Sigma \; and \; V' \beta^s = p$. As described by Magingxa et al. (2006), Σ is the $n \times l$ matrix of retained components, V is a $k \times l$ matrix of eigenvectors equivalent to the l retained components, and A^S are the standardised dependent variables. P is $l \times l$ vector of new coefficients associated with l components. Magingxa et al. (2006) and Fekedulegn et al. (2002) describe standard errors of the estimated coefficients P as symbolised by a $l \times l$ vector calculated in the form as Equation 29.

$$Var(\hat{\gamma}) = \hat{\delta}^2 \, (Z'Z)^{-1} = \hat{\delta}^2 \, diag(\lambda_1^{-1}, \lambda_2^{-1}, \ldots . \lambda_l^{-1}) \qquad [29]$$

Where $\hat{\delta}^2$ is the variance of residuals from Equation 27. The elimination of components is carried out in accordance with the procedure proposed by Fekedulegn et al. (2002). The elimination of some principal components does not change the magnitude of the variance. However, the elimination of one or more components will eventually reduce the total variance in the prediction model, which consequently results in a better prediction model (Draper & Smith, 1981; Myers, 1981). The elimination of the components can be done based on their significance from the regression results (Magingxa et al., 2006). Presume that r principal components are eliminated due to their insignificance, and then Equation 28 can be reformulated to use $k - r$ components.

$$\Psi = \beta_0^s + \sum k - r \, p_{k-r} + \varepsilon^0 \qquad [30]$$

The 0 symbol on ε^0 is used to differentiate it from ε determined in Equation 28, since they are not identical (Fekedulegn et al., 2002). The residuals differ because the vectors of coefficients have been reduced to $k - r$ components.

$$\begin{bmatrix} \alpha_{1,pc}^s \\ \alpha_{2,pc}^s \\ \cdot \\ \cdot \\ \cdot \\ \alpha_{k,pc}^s \end{bmatrix} = \begin{bmatrix} V_{11} & V_{12} \cdot & \cdot \cdot V_{1l} \\ V_{21} & V_{22} \cdot & \cdot \cdot V_{2l} \\ \cdot & \cdot \ \cdot & \\ \cdot & \cdot \ \cdot & \\ \cdot & \cdot \ \cdot & \\ V_{k1} & V_{k2} \cdot & \cdot \cdot V_{Kl} \end{bmatrix} \text{x} \begin{bmatrix} \hat{\gamma}_1 \\ \hat{\gamma}_2 \\ \cdot \\ \cdot \\ \cdot \\ \hat{\gamma}_\ell \end{bmatrix} \qquad [31]$$

Where $\hat{\gamma}_i$is the estimator of γ_i in Equation 29. The constant $\alpha_{0,pc}^s = \bar{y}$. The standardised coefficients evaluate the relative importance of the explanatory variables in determining the occurrence of predation.

Following Fekedulegn et al. (2002), variance of the principal component estimators of standardised variables is given by:

$$Var(\alpha^{s}{}_{pc}) = \Psi_{\ell}^{s} K^{S} \qquad [32]$$

Where Ψ_{ℓ}^{s} contains the squares of the elements of V_l^S in equation 24, and K^S contains the squares of the elements of the matrix of standard errors of the coefficient matrix of γ in equation 25. The corresponding standard errors for the estimators of principal components of standardised variables are given by:

$$s.e.(\alpha_{pc}^{s}) = \left[Var(\alpha_{pc}^{s})\right]^{1/2} \qquad [33]$$

Following Fekedulegn et al. (2002), standardised coefficients $\alpha_{j,pc}^{s}$ of standardised variables X_j^x were transformed back to non-standardised coefficients $\alpha_{j,pc}$ of X_j

$$\alpha_{j,pc} = \frac{\alpha_{j,pc}^{s}}{S_{xj}}, j = 1,2, \dots, k \qquad [34]$$

and

$$\alpha_{0,pc} = \alpha_{0,pc}^{s} - \frac{\alpha_{1,pc}^{s}\bar{x}_1}{S_{x1}} - \frac{\alpha_{2,pc}^{s}\bar{x}_2}{S_{x2}} - \dots - \frac{\alpha_{k,pc}^{s}\bar{x}_k}{S_{xk}} \qquad [35]$$

Where S_{xj} is the standard deviation of the j^{th} original variable X_j, and $\alpha_{0,pc}^{s}, \alpha_{1,pc}^{s}, \alpha_{2,pc}^{s}, \alpha_{k,pc}^{s}$ are coefficients of the standardised variables.

3.3.4.3 The direction of causality

The results from the respective PCR analyses indicate which factors have a significant relationship regarding the occurrence of predation and also the level of predation. The results however could not indicate the direction of causality. The Granger causality test is also used to determine the direction of the causality.

Since x and y are assumed to be stationary, use the autoregressive distributed lag (ADL) model.

$$Y_t = \alpha + \varphi_1 Y_{t-1} + \beta_1 X_{t-1} + e_t \qquad [36]$$

β_1 is a measure of the influence of X_{t-1} and if $\beta_1 = 0$ then X does not Granger-cause Y. Then if $\beta_1 = 0$ the past values of X have no explanatory power for Y, beyond that provided by past values of Y.

The Pairwise Granger Causality test must be done for the variables that have an effect on the occurrence of predation and also for the factors that have an effect on the level of predation. The Granger (1969) approach to the question of whether x causes y is to see how much of the current y (i.e. occurrence of predation) can be explained by the past values of y and then to see whether adding lagged values of x (i.e. mitigating actions) can improve the explained values. Y is said to be Granger-caused by x if x helps in the prediction of y, or equivalently if the coefficients on the lagged x's are statistically significant.

The discussion of the methodology to test the direction of causality concludes the discussion of the methodology that was used to meet the objectives of this research. Next follows a discussion of the characteristics and actions hypothesised to influence predation.

3.4 Characteristics and actions hypothesised to influence predation

The factors that affect the level of predation can be seen as the factors reducing or enhancing the level of predation. These factors will usually include non-lethal and lethal methods of managing predation. Non-lethal prevention methods are all the methods that do not kill the predators, but keep them away from the livestock. The lethal methods are all the methods that kill the predators and are usually very selective, except in the case of poison which is not selective. The variables that were considered as mitigating factors used by farmers in the North West province include managerial factors such as: calving in January, February, March, April, May, June, July, September, October, November; dehorning, pregnancy testing, size of breeding herd, age of first breeding, farmers also farms with sheep; lethal methods such as hunting by the farmer, use of poison, use of foothold traps, use of hunting dogs and non-lethal methods such as the use of herdsmen, kraaling, guarding dogs, electric fences.

The different factors that were hypothesised in the study to reduce predation and also the level of predation are shown in Tables 3.4 (a), (b), (c). All the factors could be put into four groups namely: socio-economic factors, managerial factors, non-lethal methods and lethal methods.

Table 3.4 (a) Socio-economic variables affecting predation on farms and their expected influence on predation in the North West province

Variable	Description	Expected influence
Socio economic factors		
Farming size	Continuous variable (farming area in hectares)	-
Age of respondent	Continuous variable	+
Completion of school	Dummy variable, code 1 yes and 0 otherwise	+
Further studies in agriculture	Dummy variable, code 1 yes for further studies and 0 otherwise	+
Member of a farmer’s association	Dummy variable, code 1 yes and 0 if not a member of a farmer’s association	+
Member of a producer’s association	Dummy variable, code 1 yes and 0 if not member of a producer’s association	+
Experience as a farmer	Continuous variable	+

The expected influence that each of the different socio-economic variables may have on predation (occurrence as well as level of predation) is shown in Table 3.4(a).

The socio-economic factors in Table 3.4 (a) are explained as follows:

All the socio-economic factors shown are expected to have a positive effect on predation, except farm size. It is hypothesised that factors such as: the higher the age of farmers, completion of school, further studies in agriculture, being a member of a farmer’s association, being a member of a producer’s association and long experience, all help the farmer to make better decisions in prevention of predation, while larger farm size makes it more difficult for the farmer to control predation. The larger the farm the more difficult it becomes to control predation, due to the fact that the farmer must divide his attention and his resources.

Table 3.4 (b) Predation management variables affecting predation on farms and their expected influence on predation in the North West province

Managerial factors		
Size of breeding herds	Continuous variable	-
Calving in January	Dummy variable, coded 1 for calves in January and 0 otherwise	-
Calving in February	Dummy variable, coded 1 for calves in February and 0 otherwise	-
Calving in March	Dummy variable, coded 1 for calves in March and 0 otherwise	-
Calving in April	Dummy variable, coded 1 for calves in April and 0 otherwise	-
Calving in May	Dummy variable, coded 1 for calves in May and 0 otherwise	+
Calving in June	Dummy variable, coded 1 for calves in June and 0 otherwise	+
Calving in July	Dummy variable, coded 1 for calves in July and 0 otherwise	+
Calving in August	Dummy variable, coded 1 for calves in August and 0 otherwise	+
Calving in September	Dummy variable, coded 1 for calves in September and 0 otherwise	+
Calving in October	Dummy variable, coded 1 for calves in October and 0 otherwise	-
Calving in November	Dummy variable, coded 1 for calves in November and 0 otherwise	-
Calving in December	Dummy variable, coded 1 for calves in December and 0 otherwise	-

Calving on natural land	Dummy variable, coded 1 for calves on natural land and 0 otherwise	-
Calving on pastures	Dummy variable, coded 1 for calves on pastures and 0 otherwise	+
Calving on crop residues	Dummy variable, coded 1 for calves on crop residues and 0 otherwise	+
Calving in the kraal	Dummy variable, coded 1 for calves in the kraal and 0 otherwise	+
Times counted per month	Continuous variable	+
Times worked with livestock per month	Continuous variable	+
Age at first conception	Continuous variable	-
Pregnancy testing	Continuous variable	+
Dehorn	Dummy variable, coded 1 for dehorn and 0 otherwise	-
Removal of death animals	Dummy variable, coded 1 for removal of dead animals and 0 otherwise	+
Recording of difficult births	Dummy variable, coded 1 for recording difficult births and 0 otherwise	+
Sheep	Dummy variable, coded 1 for also farming with sheep and 0 otherwise	+

The managerial factors in Table 3.4 (b) are explained as follows:

Some of the managerial factors are expected to contribute positively, while others may be negative for control of predation, as shown in Table 3.4 (b). This is mainly due to the fact that some of the factors, such as calving of especially heifers, are correlated with high food needs of predators (Marker & Potgieter, 2011). For instance, during the breeding season of predators they need to provide for their young and during the time predation is normally higher. The age of first calving is also very important relating to predation, because if the animals are mated too early they have difficulty giving birth, which is a perfect time for predators to attack. Dehorning is also expected to be negatively associated with predation due to the fact that if farmers dehorn their cattle they lose their defensive weapons. The farmer's decision as to whether to dehorn may be difficult, because if they dehorn then their cattle become defenceless, but if they don't dehorn then the cattle tend to injure each other, which may also lead to deaths.

Table 3.4 (c) Other predation management variables affecting predation on farms and their expected influence on predation in the North West province

Non-lethal methods		
Herdsmen	Dummy variable, coded 1 herdsmen and 0 otherwise	+
Electric fences	Dummy variable, coded 1 for electric fences and 0 otherwise	+
Kraaling	Dummy variable, coded 1 for kraaling and 0 otherwise	+
Guarding animals	Dummy variable, coded 1 for use of guarding animals and 0 otherwise	+
Lethal methods		
Farmer himself hunts	Dummy variable, coded 1 for self hunt and 0 otherwise	+
Specialist hunters	Dummy variable, coded 1 for use of specialist hunter and 0 otherwise	+
Foothold traps	Dummy variable, coded 1 for use of foothold traps and 0 otherwise	+
Cage traps	Dummy variable, coded 1 for use of cage traps and 0 otherwise	+
Hunting with dogs	Dummy variable, coded 1 for use of hunting dogs and 0 otherwise	-/+
Poison	Dummy variable, coded 1 for use of poison and 0 otherwise	-/+

Some of the managerial factors are expected to have an effect on the occurrence of predation, but are not necessarily expected to influence the level of predation. For instance, if the cattle calve in kraals, the occurrence of predation may be less, but it may not necessarily have an effect on the level of predation. Van Niekerk (2010) reported that lambing of sheep in protected areas reduces the occurrence of predation, though it did not have a significant effect on the level of predation.

The lethal methods and non-lethal methods of controlling predation in Table 3.4 (c) are explained as follows:

It is expected that lethal methods will reduce the level of predation but, will not necessarily affect the occurrence of predation, while non-lethal methods will reduce the occurrence of predation, but will not influence the level of predation. The reduction in the level of predation due to the use of lethal methods can be explained as follows: when farmers use lethal control methods they reduce the number of predators on farms and thereby reduce the number of attacks, but attacks will still happen because new predators will enter the farm.

The reduction in the occurrence of predation can be explained as follows: when farmers use non-lethal control methods such as jackal proof fences, they keep predators out of the farm and thus reduce the occurrence of predation. There are also some important cases where lethal and non-lethal methods can reduce both the occurrence and also the level of predation.

Some of the factors in Table 3.4 (c) were also hypothesised to have a positive and/or negative effect on predation, e.g. poison and hunting with dogs. This is due to the "vacuum" effect that is caused by the two variables. For this reason it is important to use control methods selectively, because if farmers kill predators that are not killing livestock, the "vacuum" effect may attract new predators that do kill livestock. In such a case, the unselective use of control methods may actually promote predation.

The discussion of the hypothesised determinants of predation among cattle concludes this chapter. The next chapter focuses on the results that were obtained through this research.

Chapter 4
Results and discussion

4.1 Introduction

This chapter is divided into three sections and covers the results obtained from the analyses. Firstly, the direct and indirect losses due to predation in the North West province are covered. Secondly, the underlying structures in predation prevention practices used by farmers in the province are discussed. Thirdly factors that influence predation in the province and also the best management practices are discussed. The data used in these sections were derived from the 238 interviews conducted in the four magisterial districts a as well as additional information about the North West province.

4.2 Descriptive analyses of the North West province

The North West province has the second largest number of cattle in South Africa and was the focus of this study. Relevant information for the other provinces is provided as **appendices**.

The total number of farmers, head of cattle and grazing land in the North West province are shown in Table 4.1. A total of 238 farmers were interviewed, which represents a sample of 5.8% of the total of 4 135 farmers in the province (NDA, 2007). It is also estimated that there are 1 221 538 head of cattle and 6 738 014 ha of grazing land in the North West province (NDA, 2012). The grazing land comprises 56.8% of the North West province. The sample of respondents farmed with 122 780 head of cattle on 546 120 ha of land (10% and 8.1% of the total number of cattle and total grazing land in the North West province respectively).

The percentage of cattle breeds of the respondents in the North West province is presented in Figure 4.1. The responding farmers in the North West province favoured three breeds namely Bonsmara, Simbra and Simmentaler (Figure 4.1). this choice of beef cattle breed is not necessarily the same as for the province as a whole..

Table 4.1 Number of farmers surveyed, land utilisation and cattle numbers in the North West province

	Surveyed	North West	Percentage
Farmers	238	4 135	5.8
Head of cattle	122 780	1 221 538	10
Grazing land (ha)	546 120	6 738 014	8.1

Source: NDA, 2012

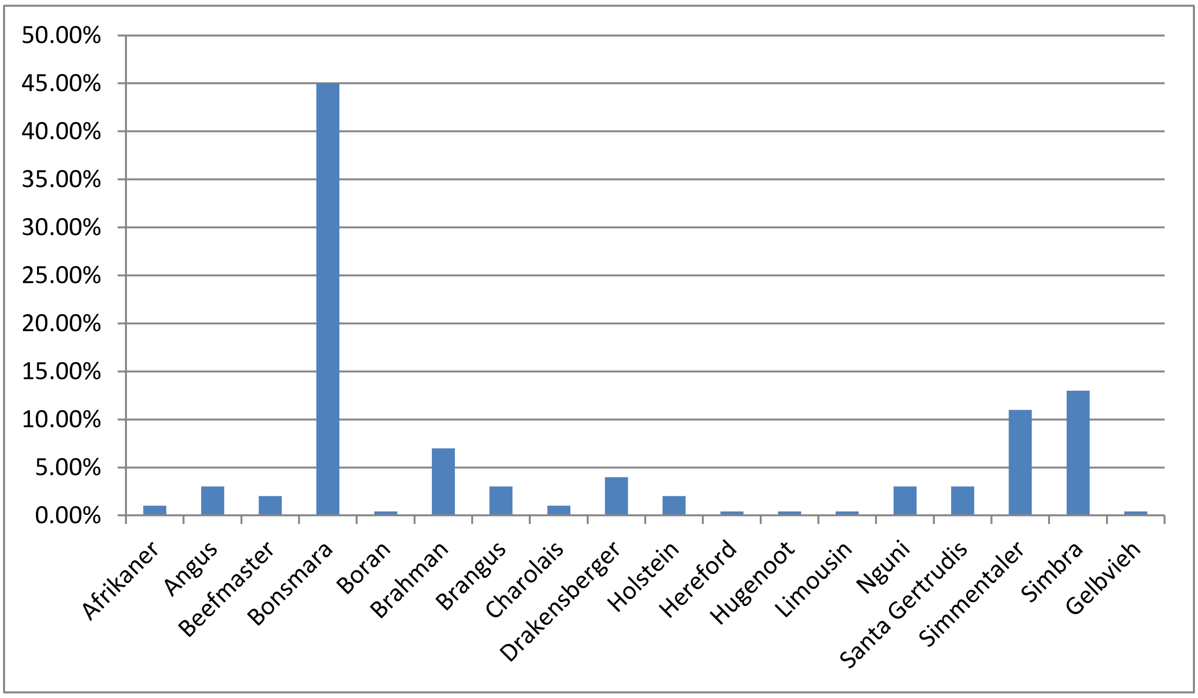

Figure 4.1 Cattle breeds of respondents surveyed in the North West province.

4.2.1 Characteristics of respondents

A summary of the characteristics of the respondents surveyed in the North West province is shown in Table 4.2.

Table 4.2 A summary of the characteristics of the respondents in the North West province

	Average	Minimum	Maximum	Standard deviation
Age of respondents (years)	50.58	23	78	11.88
Farm size (ha)	2036.25	21	16 000	2440.69
Completion of school (%)	65	-	-	0.48
Further studies in agriculture (%)	35	-	-	0.48
Member of a farmer association (%)	82	-	-	-0.39
Members of a producer association (%)	95	-	-	-0.23

The average age of the farmers in the North West province was 50.58 years (Table 4.2). It is a matter of concern that the average age of farmers is so high. It means that fewer young people are farming, and prefer to search for jobs in other industries. This is probably because farm prices are very high and they do not have the money to start farming at a young age. The average farm size in the North West province is large at 2036 ha/farmer. This shows that farmers in the North West province are farming on large farms, thus opting for better economy of scale. The province is losing small farmers and the large farmers are getting larger. This may have an effect on predation, because larger farms may suggest less control over livestock.

Only 65% of the farmers in the North West province had completed school (Table 4.2). For further studies, 35% of the farmers in the North West province continued their studies in agriculture. This shows that most of the farmers in the province returned to farm after completing school at a young age. It may suggest that farmers are lacking education, but the lack of education is made up for by their experience as farmers.

A high proportion (82%) of the farmers surveyed in the North West province (Table 4.2) is members of farmers associations and 95% are members of producer associations. This shows that they want to share their experience and also learn more from the other farmers.

4.3 The costs of predation in the North West province

The costs of predation in the North West province were divided into two groups, namely the direct and the indirect costs of predation. The direct costs are the costs associated with the loss of livestock. The indirect costs of predation are all the costs associated with the prevention of predation.

It is important to calculate the direct and indirect costs of predation to understand the full extent of the problem.

4.3.1 The direct costs of predation in the North West province

There are a number of ways to calculate the costs of predation. The most common method of illustrating the direct costs is to use the market price of the animal lost and multiply it by the number of livestock lost. This method is the most useful, because it is very difficult to calculate the value of an animal if it was not yet at the point of sale. The average losses in the study are shown in Table 4.3. The Bojanala Platinum district showed the highest predation (1.03%) and the Southern district the lowest (0.29%) (Table 4.3).

Table 4.3 The number of cattle lost to predation in different magisterial districts in the North West province

Magisterial districts	Number of cattle killed	Number of cattle surveyed	Average predation losses (%)
Bojanala Platinum	151	14 726	1.03
Ngaka Modiri Molema District	101	25 346	0.40
Bophirima District	276	46 912	0.59
Southern District	103	35 796	0.29
Total	**631**	**122 780**	**0.51**

The losses associated with predation in the North West province are ascribed to different predators in Figure 4.2. Three predators are mostly implicated for cattle predation in the North West province, namely black-backed jackal, leopard and caracal (Figure 4.2). Together these predators account for more than 93% of the losses in the province while the rest of the losses are attributed to dogs and brown hyaena.

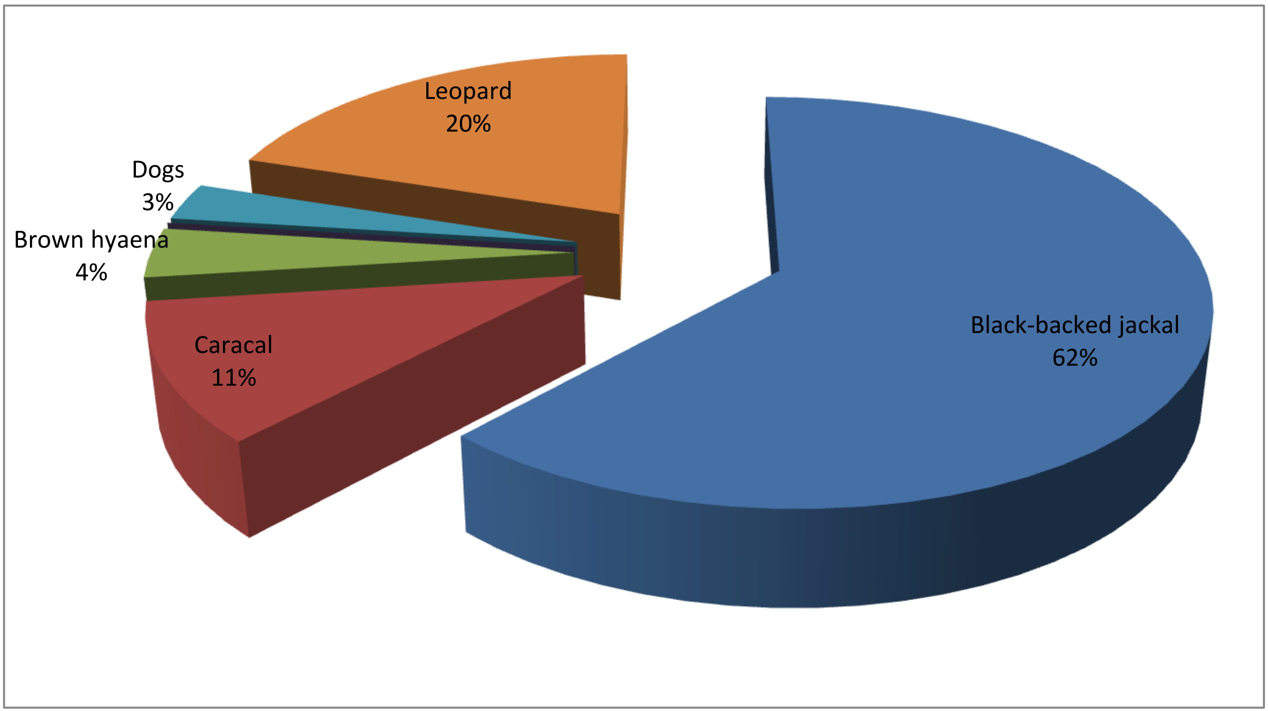

Figure 4.2 Predator species responsible for predation losses in the North West province.

Predation losses are relatively low (0.51%) for the North West province, but there are some districts within the province that experience higher losses due to predation. The relatively low predation losses do not mean that the financial losses or direct costs of predation are small.

The direct costs of predation in the North West province were calculated as follows:

$$N \times A = L \quad [39]$$

$$L \times U = C \quad [40]$$

where N is the number of cattle in the North West province, A is the average predation losses, L is the total losses due to predation in the North West province, U is the unit cost per animal and C is the total direct cost of predation in the North West province.

The direct cost of predation in the North West province was ZAR 67 776 800 (Table 4.4). The monetary value of ZAR 10 400 / unit of livestock at point of sale was provided by the National Stock Theft Forum of the Red Meat Producers' Organisation in 2012. The predation on cattle is less than that for small livestock (Van Niekerk, 2010), but it also shows that even a small number of predation losses may have a large financial impact on the farmers.

Table 4.4 The direct cost of predation on cattle per district in the North West province

Magisterial districts	Number of cattle in the province	Average predation losses (%)	Losses due to predators	Unit cost per animal (ZAR)	Cost of predation (ZAR)
Bojanala Platinum	184 276	1.03	1898	10 400	19 739 200
Ngaka Modiri Molema	253 005	0.40	1012	10 400	10 524 800
Bophirima	444 674	0.59	2 623	10 400	27 279 200
Southern	339 583	0.29	984	10 400	10 233 600
Total	**1 221 538**	**-**	**6 517**	**-**	**67 776 800**

4.4 The indirect costs of predation management in the North West province

As stated previously the indirect costs of predation control are all the costs associated with the prevention of predation. It is not easy to estimate the indirect costs of predation control because it is difficult for farmers to set a price tag on activities to prevent predation. Farmers do not always record the extra labour, fuel, time, etc. that they have spent to set up predation control systems.

The indirect costs of predation can further be divided into lethal and non-lethal costs, as set out in the following section.

4.4.1 Costs of lethal predation management

The costs of lethal control of predation include all the costs associated with methods and activities that could kill predators, namely: farmers themselves are hunting predators, hiring specialist hunters, foothold traps, cage traps, hunting with dogs and poison.

The lethal costs of predation control in the North West province are shown in Table 4.5 and were calculated as,

$$T / N = R \quad [41]$$

$$R \times N = K \quad [42]$$

where T is the total lethal cost of predation control in the study, N is the number of cattle in the study, R is the lethal cost per unit of livestock, N is the number of cattle in the province and K is the total lethal cost.

Table 4.5 Costs of lethal predation management in the North West province

Magisterial districts	Total lethal cost in study (ZAR)	Number of cattle in study	Lethal cost per unit of livestock (ZAR/head)	Number of cattle in province	Total lethal cost (ZAR)
Bojanala Platinum	106 800	14 726	7.25	184 276	1 336 001
Ngaka Modiri Molema	183 300	25 346	7.23	253 005	1 829 226
Bophirima	314 100	46 912	6.70	444 674	2 979 316
Southern	138 000	35 796	3.86	339 583	1 310 790
Total	**742 200**	**122 780**	**-**	**1 221 538**	**7 455 333**

The total lethal cost of preventing predation on cattle in the North West province was calculated to be ZAR 7 455 333. The Bophirima district had the highest cost of preventing predation for the district municipalities in the North West province and the Southern district had the lowest cost. According to the information in Tables 4.4 and 4.5, the Southern district had the smallest percentage of predation and, therefore, the farmers were spending less on control. The district with the highest predation was the Bojanala Platinum district (Table 4.3), but they did not have the highest lethal cost of predation. This may have been because they were using more non-lethal methods to preventing predation.

The percentage of farmers using methods to prevent predation in the North West province is illustrated in Figure 4.3. This survey includes both lethal and non-lethal prevention methods. In the North West province only 38% of cattle farmers also had a small livestock enterprise. In general, due to the minor presence of small livestock in the North West province, predation control is not widely practised. The combination of a low percentage of farmers using predation prevention methods and the low number of small livestock farmers in the province may be the underlying reason for the overall low level (37%) of predation management.

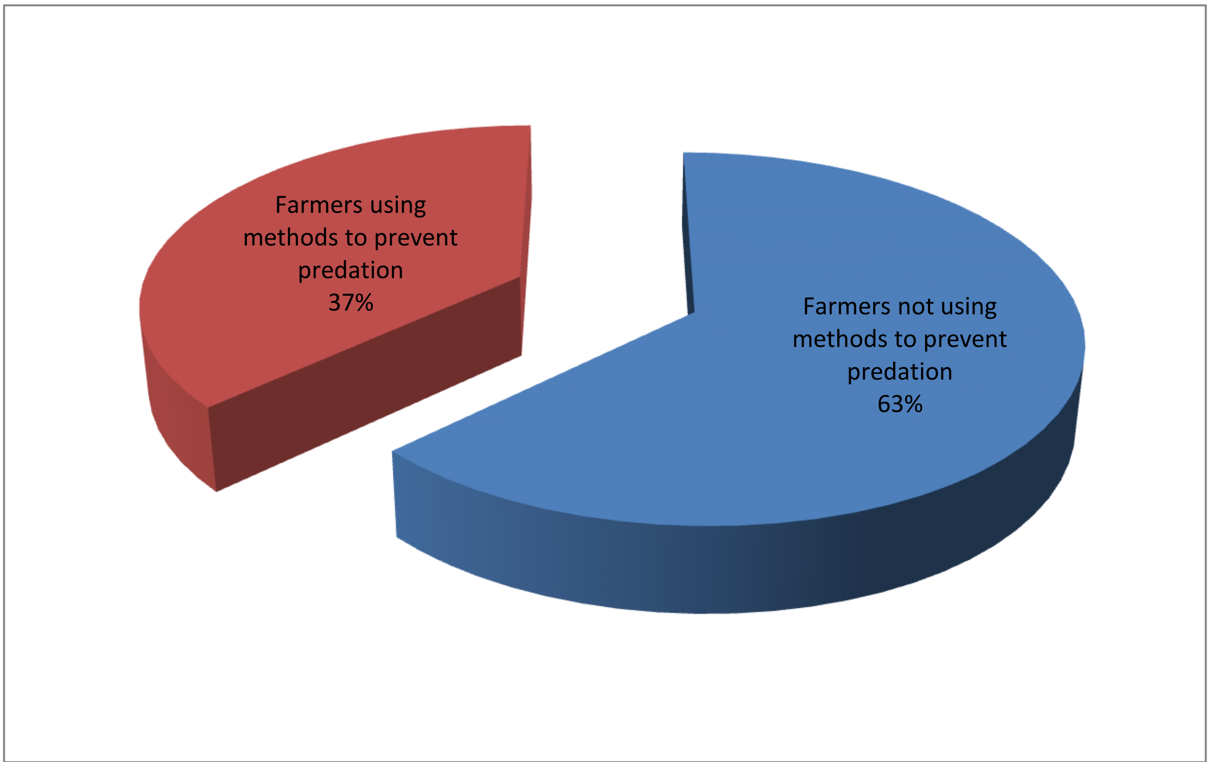

Figure 4.3 Percentage of farmers using predation management methods in the North West province.

The percentage use of lethal prevention methods in the North West province is illustrated in Figure 4.4. The percentage shown is the number of farmers that use any prevention methods. Farmers who hunt themselves on their farms is the most common method (41%), followed by hiring of specialist hunters (16%) and poison (13%). It is illustrated in Figure 4.4 that farmers don't use methods such as foothold traps, cage traps or hunting with dogs frequently. This may be because these three methods require skills, time, labour and upkeep to do correct.

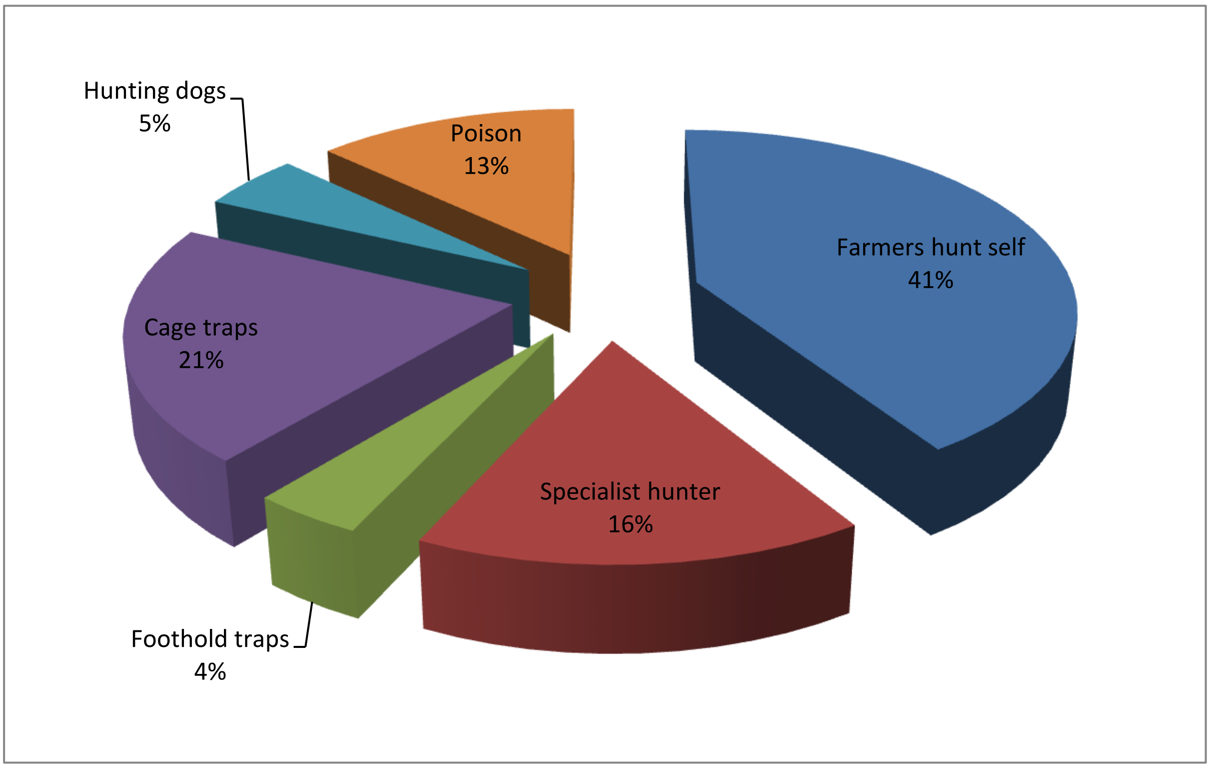

Figure 4.4 Percentage use of lethal methods in the North West province.

The number of predators reported to have been killed by respondents in this study by lethal methods in the North West province is illustrated in Figures 4.5. Black-backed jackal, caracal and leopard are the three predators that killed cattle most frequently.

The number of predators that were reported to have been killed per district in the North West province is shown in Figure 4.6.

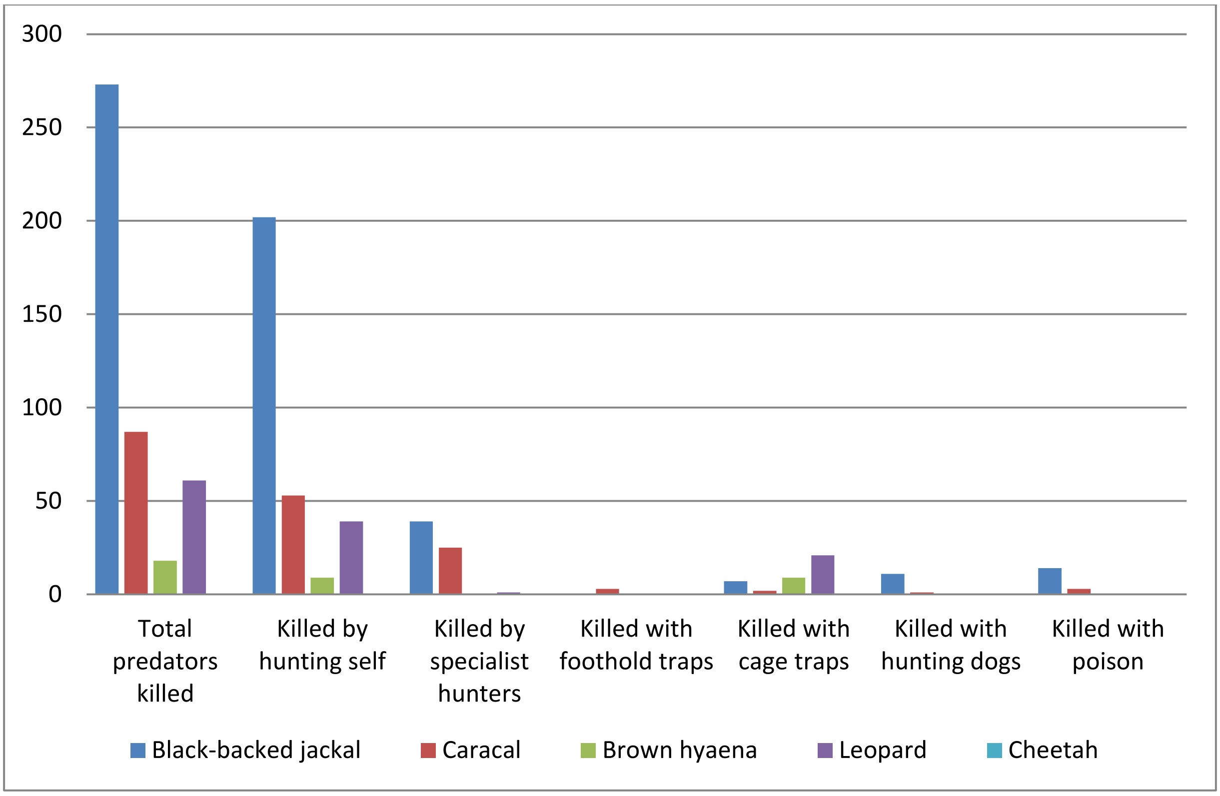

Figure 4.5 Number of predators killed with lethal methods in the North West province.

Most of the predators in the North West province were killed (199) in the Bophirima district (Figure 4.6). This may be because there are more predators or that farmers are spending more time and money on preventing predation. The conclusion that can be drawn after viewing Tables 4.4 and 4.5 and Figure 4.6, is that the Bophirima district has the highest financial losses, largest management cost and also the highest number of predators that were killed. This is because the Bophirima district is the largest district in the North West province and therefore there are more cattle and also more predators. The district with the highest percentage of predation is the Bojanala Platinum district and this district also reported the least number of predators killed, but has the highest lethal cost per unit. This suggests that the Bojanala district is overspending on preventing predation on cattle or that the farmers in this district do not have the necessary knowledge to effectively prevent predation. It may be that the farmers are not getting the results that they are hoping for by using the methods.

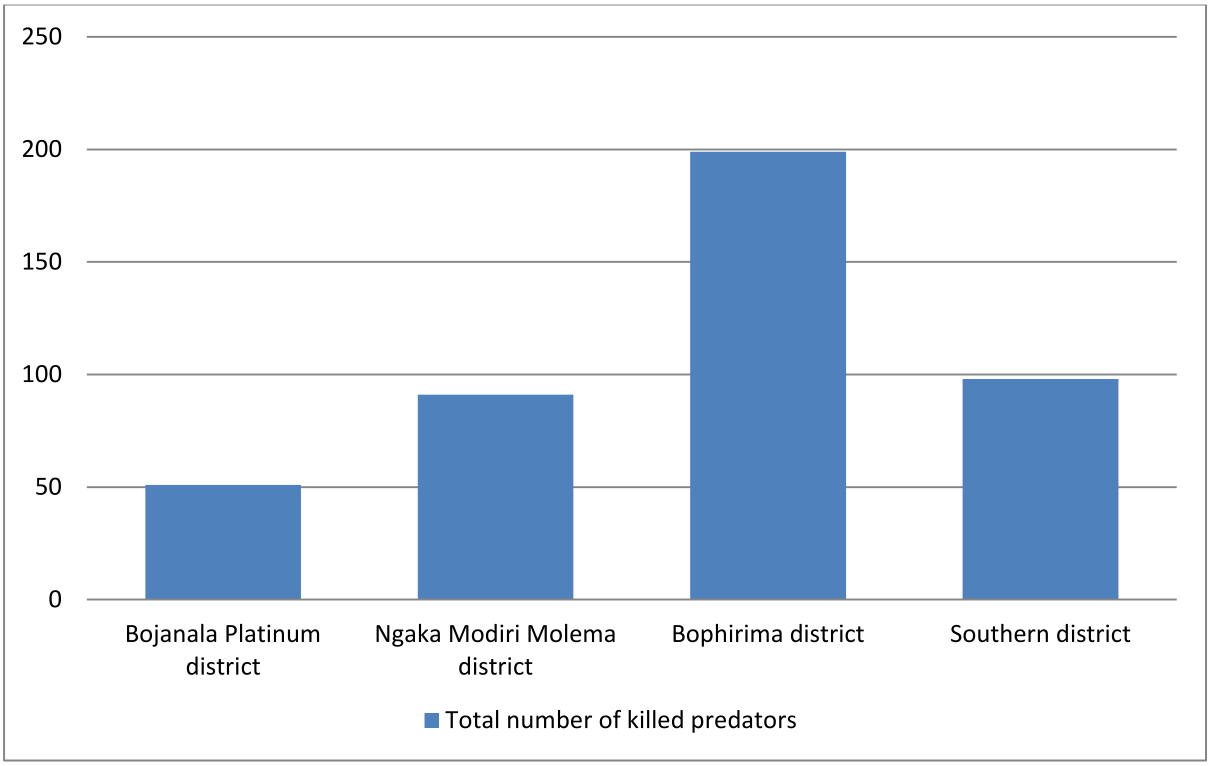

Figure 4.6 Total number of predators killed with lethal methods in the different districts of the North West province (2011-2012).

4.4.2 Costs of non-lethal predation management

The costs of non-lethal predation management include all the costs that do not kill predators, but prevent or reduce predation, namely: herdsmen, electric fences, jackal proof fences, kraaling and guarding dogs.

The costs of non-lethal predation management in the North West province are shown in Table 4.6. The total non-lethal cost of managing predation in the North West province was estimated as ZAR 9 087 653. The non-lethal costs of managing predation are even higher than the lethal costs. The Bophirima district reported the highest cost of managing predation and the Bojanala Platinum district the lowest cost. Farmers in the Bojanala Platinum district is spending very little on non-lethal predation management methods (Table 4.6), compared to their spending on lethal predation management methods (Table 4.5).

Table 4.6 Costs of non-lethal predation management in the North West province

Magisterial districts	Total cost in study (ZAR)	Number of cattle in study	Non-lethal cost per unit (ZAR/head)	Number of cattle in province	Total non-lethal cost (ZAR)
Bojanala Platinum	33 000	14 726	2.24	184 276	412 778
Ngaka Modiri Molema	130 000	25 346	5.13	253 005	1 297 916
Bophirima	622 200	46 912	13.26	444 674	5 896 377
Southern	156 200	35 796	4.36	339 583	1 480 582
Total	**941 400**	**122 780**		**1 221 538**	**9 087 653**

The percentage use of non-lethal management methods in the North West province are illustrated in Figure 4.7. The percentage shown relates to the number of farmers that use any management methods. Herdsmen are used most (58%) of the time, followed by kraaling (30%), electric fences (3%), and guarding dogs (9%). No jackal proof fences were used.

Many of the farmers were hesitant to answer some of the questions in the survey, because they thought that the study was conducted by the government and that there would be consequences if they admit to killing predators. A number of farmers did not admit to killing predators, but when convinced about the credibility of the interviewers they started opening up and provided information, discussed problems and methods used. This means that a large number of the 63% farmers who said they do not use any predation management methods, might in fact be using some methods, but did not trust the interviewer to openly admit it.

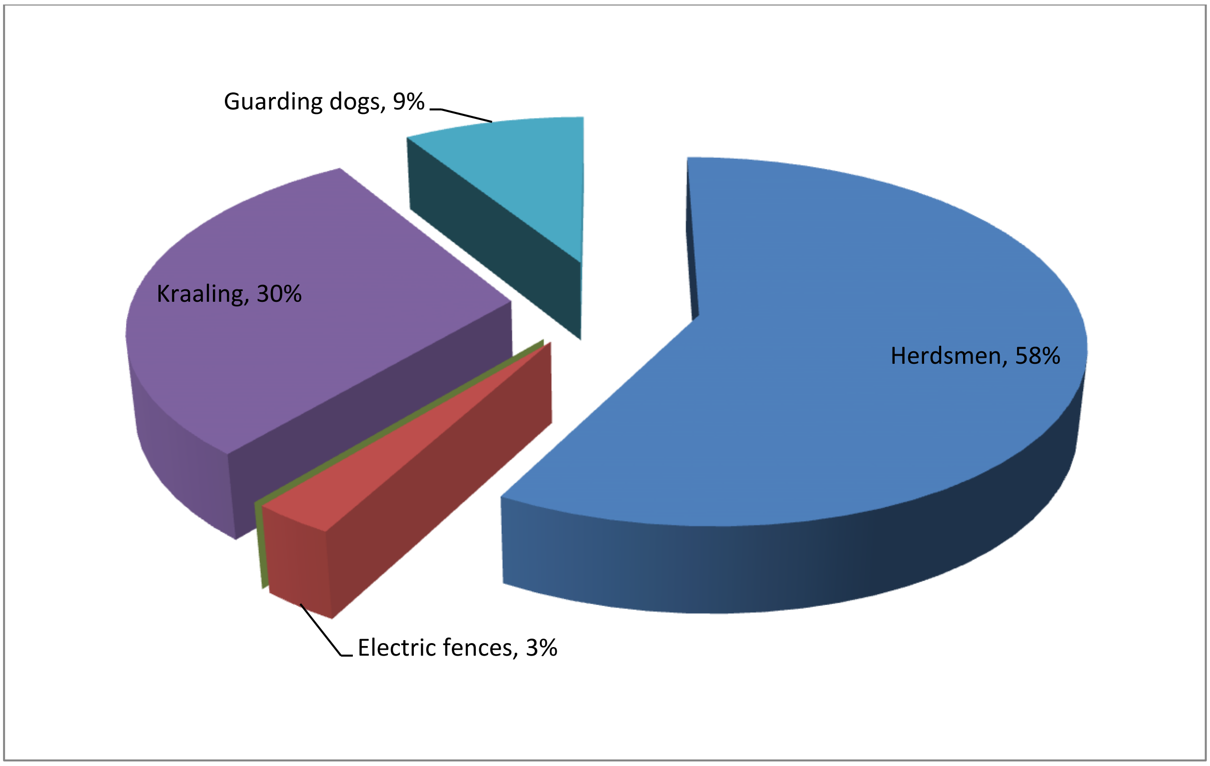

Figure 4.7 Percentage use of non-lethal management methods to prevent predation in the North West province.

4.5 Total cost of predation in the North West province

The total cost of predation includes the direct and indirect cost (lethal and non-lethal) of predation. The total cost of predation in the North West province for a period of one year is shown in Table 4.7. The Bophirima district has the largest losses of ZAR 36 million, followed by the Bojanala Platinum district with a loss of ZAR 21 million and then the Ngaka Modiri Molema and Southern districts, each with about ZAR 13 million losses. Although the total cost of predation in the Bophirima district is the largest, it has only the second largest percentage of predation (Table 4.3) and while Bojanala Platinum district reported the largest percentage of predation (Table 4.3), its cost of predation is only the second largest. This suggests that these two districts may be ineffective in managing predation.

Table 4.7 The total direct and indirect cost of predation in the North West province

Magisterial districts	Total lethal cost (ZAR)	Total non-lethal cost (ZAR)	Total cost of predation (ZAR)	Total direct and indirect cost (ZAR)
Bojanala Platinum	1 336 001	412 778	19 739 200	21 487 979
Ngaka Modiri Molema	1 829 226	1 297 916	10 524 800	13 651 942
Bophirima	2 979 316	5 896 377	27 279 200	36 154 893
Southern	1 310 790	1 480 582	10 233 600	13 024 972
Total	**7 455 333**	**9 087 653**	**67 776 800**	**84 319 786**

4.6 Investigating the underlying structure of factors causing predation in the North West province

A factor analysis was conducted to determine the underlying structure in the predation management practices used by farmers in the North West province. The first step was to perform a factor analysis to reduce the data size as discussed previously in Chapter 3.

As shown in Table 4.8, the overall Measure of Sampling Adequacy (MSA) for the set of variables included in the analysis was 0.745, which exceeds the minimum requirement of 0.50 for overall MSA. The twenty variables remaining in the analysis satisfy the criteria for appropriateness of factors analysis (Table 4.8). The Bartlett test ($p<0.01$) shown in Table 4.8 satisfies the requirements.

Table 4.8 Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.745**
Bartlett's Test of Sphericity	Approx.Chi-Square	2077.240
	df	190
	Sig.	.000

The communalities are reported in Table 4.9 and explain the proportion of the variance in the original variables that is accounted for by the factor solution. The factor solution should explain at least half of each original variable's variance, so the communality value for each variable should be at least 0.50 or higher. All the variables in Table 4.9 have communalities greater than 0.50, which indicates that the factors explain more than 50% of the variation in the variables.

Table 4.9 Results of the communalities

	Initial	**Extraction**
Size of breeding herd	1.000	0.695
Calving in January	1.000	0.800
Calving in February	1.000	0.879
Calving in March	1.000	0.785
Calving in April	1.000	0.764
Calving in May	1.000	0.836
Calving in June	1.000	0.783
Calving in July	1.000	0.716
Calving in September	1.000	0.729
Calving in October	1.000	0.860
Calving in November	1.000	0.715
Age at first conception	1.000	0.823
Pregnancy testing	1.000	0.666
Dehorn	1.000	0.638

	Initial	Extraction
Sheep	1.000	0.621
Herdsmen	1.000	0.639
Hunting with dogs	1.000	0.828
Poison	1.000	0.554
Farmer himself hunts	1.000	0.621
Foothold traps	1.000	0.715

After all the communalities with values lower than 0.50 were removed it is possible to see the total variance in the variables. The total variance that could be explained in the variables is shown in Table 4.10. The eight (8) components explain 73.341% of the total variance in the variables which are included in the components.

Table 4.10 Percentage variance explained

	Rotation Sum of Squared Loadings		
Component	**Eigen value**	**% of variance**	**Cumulative %**
1	4.885	24.425	24.295
2	2.174	10.870	35.295
3	1.539	7.696	42.991
4	1.415	7.076	50.067
5	1.311	6.556	56.623
6	1.127	5.635	62.258
7	1.123	5.616	67.874
8	1.093	5.467	**73.341**

The different variables that were grouped together to reduce the number of variables is shown in Table 4.11. The variables are grouped in eight components determined by their communalities for West province. Principal component (PC 1) has seven variables that include: calving in January, February, March, April, May, June and July. The combined name that was given is ‘calving whole year round’. The second PC (PC 2) includes September, October and November and the new name for PC 2 is ‘summer calving season’. The third PC (PC 3) includes size of breeding herd, pregnancy testing, dehorn, and the combined name is ‘management practices’. The PCs 4, 6, 7 and 8 include only one variable and the names for these PCs were ‘poison’, ‘foothold traps’, ‘age at first conception’ and ‘hunting with dogs’, respectively. The PC 5 includes sheep and herdsmen and the combined name is ‘prevention and reduction’.

Table 4.11 Results from the Rotated Component Matrix

	Component							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Calving in January	**0.872**	-0.039	-0.093	0.028	0.047	-0.104	0.125	-0.016
Calving in February	**0.907**	-0.050	-0.131	0.045	0.100	-0.123	0.099	-0.022
Calving in March	**0.846**	0.127	-0.110	-0.063	0.167	0.006	0.066	0.068
Calving in April	**0.727**	0.223	-0.027	-0.216	-0.007	0.264	-0.236	0.112
Calving in May	**0.729**	0.249	0.091	-0.142	-0.194	0.334	-0.254	0.022
Calving in June	**0.795**	0.311	0.011	0.007	-0.188	0.134	0.003	-0.017
Calving in July	**0.796**	0.204	-0.096	0.044	-0.122	-0.062	0.099	0.031
Calving in September	0.313	**0.658**	-0.062	0.117	-0.196	-0.334	0.133	-0.110
Calving in October	0.106	**0.913**	-0.019	0.083	-0.069	-0.024	0.049	0.001
Calving in November	0.305	**0.707**	0.081	-0.066	0.082	0.288	-0.106	0.101
Size of breeding herd	0.019	-0.306	**0.503**	0.245	-0.179	-0.290	-0.288	-0.296

Pregnancy testing	-0.127	0.045	**0.787**	0.001	0.113	0.025	0.036	-0.120
Dehorn	-0.115	0.009	**0.751**	-0.054	-0.010	0.023	0.054	0.234
Sheep	0.010	-0.168	0.015	-0.164	**0.717**	0.201	-0.053	-0.096
Herdsmen	-0.019	0.052	0.054	0.167	**0.747**	-0.217	-0.016	-0.001
Farmer himself hunts	-0.088	0.013	0.097	**0.773**	0.010	0.015	-0.045	-0.059
Foothold traps	0.056	-0.013	-0.010	0.389	-0.057	**0.696**	0.227	-0.143
Hunting with dogs	0.077	-0.006	0.049	0.117	-0.092	-0.084	-0.004	**0.889**
Poison	0.011	0.087	-0.137	**0.654**	0.010	0.160	-0.054	0.266
Age at first conception	0.097	0.043	0.051	-0.082	-0.070	0.112	**0.886**	-0.001

Farms in the North West province can be divided into those that have a summer calving season (PC 2) and those where calving takes place the all year round (PC 1) (Table 4.11). This difference in calving seasons may have an effect on predation. Farmers in the North West province use management practices to reduce predation, such as size of breeding herd, pregnancy testing and dehorning (PC 3) (Table 4.11). This may also affect predation, because if the herds are large farmers may have less control and predation may be higher. Dehorning may also have an effect, because if the cattle have horns they can defend themselves, but if they are dehorned they may be more vulnerable to predation. Pregnancy testing informs farmers of the number of pregnant cows: if they see a sudden drop in birth rate, the farmers will know something is wrong. If pregnancy testing was not done the farmer would not know how many calves should have been born, so if the number of calves born is fewer than they expected they could easily blame it on predation and not conception. The age of first conception (PC 7) is also important to farmers in the North West province, because if cattle are younger than the normal age of conception they may have difficulty with calving. When calving is difficult, the calving time and the recovery time for the freshly calved cow/heifer will be longer and this condition will be beneficial for predators. The rest of the PCs have to do with controlling of predators, except PC 5 (sheep and herdsmen).

4.7 Factors that influence predation in the North West province

For the purpose of analysis, the factors that influence predation in the North West province will be explored in two ways. Firstly, the focus is on factors that influence the occurrence of predation, and then secondly followed by exploring the factors that influence the level of predation.

To understand this section a short review will be given of the chosen methodology, in order to better understand the factors that influence predation in the North West province.

- Factors affecting livestock predation.
    - ✓ The Logit regression will identify factors that affect the occurrence of predation.
        - ➢ The results will indicate which factors have a significant relationship with the **occurrence of predation**, but the direction of causality (coefficient) cannot be determined. Therefore, the Granger Causality test must be done.
    - ✓ The Truncated regression will identify factors that affect the level of predation.
        - ➢ The results will indicate which factors have a significant relationship with the **level of predation**, but the direction of causality cannot be determined. Therefore, the Granger Causality test must be done.
    - ✓ The Granger Causality test.
        - ➢ The Granger Causality test from the Logit regression.
            - ▪ The Granger Causality test is used to determine the direction of causality for the results that were obtained in the Logit regression.

The variables that are significant in both the Logit regression and the Granger Causality test can then be interpreted. A positive coefficient will mean that it will have a positive effect on predation, meaning a higher **occurrence of predation**. A negative coefficient will mean that it will have a negative effect on predation, meaning a reduction in the **occurrence of predation.**

- The Granger Causality test from the Truncated regression.

  - Similarly in the case of the Truncated regression, a positive coefficient will mean that it will have a positive effect on predation, meaning a higher **level of predation**. A negative coefficient will mean that it will have a negative effect on predation, meaning a reduction in the **level of predation**.

4.7.1 Factors that influence the occurrence of predation

The factors that influence the occurrence of predation are all the factors that could prevent predation. The variables that have an influence on the occurrence of predation are shown in Table 4.12. Since the aim is not to predict the probability of occurrence, a significance level of 15% is accepted. The aim is rather to identify the characteristics and actions associated with a lower probability of occurrence.

Table 4.12 Results of Logit regression to identify mitigating factors that affect the occurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio-economic factors		
Size of farm	0.092	**0.130***
Farmer’s age	-0.021	0.894
Completion of school	-0.080	**0.135***
Further studies in agriculture	-0.104	**0.137***

Member of a farmer’s association	0.097	0.155
Member of a producer’s association	0.019	0.663
Experience as a farmer	0.064	0.643
Managerial factors		
Size of breeding herd	0.135	**0.131***
Calving in January	-0.002	0.887
Calving in February	0.021	0.225
Calving in March	0.047	0.333
Calving in April	0.036	0.252
Calving in May	0.030	**0.123***
Calving in June	-0.013	0.664
Calving in July	-0.011	0.650
Calving in August	-0.065	**0.116***
Calving in September	0.005	0.937
Calving in October	0.030	0.226
Calving in November	0.044	**0.111***
Calving in December	-0.034	0.505
Calving on grazing land	0.054	0.515
Calving on pastures	-0.059	0.544
Calving on crop residues	-0.051	0.393
Calving in the kraal	0.004	0.971
Times counted per month	0.028	0.804
Times worked with livestock per month	-0.085	0.170
Age at first conception	-0.087	**0.136***
Pregnancy testing	-0.024	0.565
Dehorn	0.049	0.537
Removal of dead animals	-0.076	0.187
Recording of difficult births	-0.230	0.193
Sheep	-0.030	0.632
Non-lethal methods		
Herdsmen	0.172	0.198
Electric fences	-0.221	0.187

Kraaling	0.052	0.645
Guarding animals	0.122	**0.094****
Lethal methods		
Farmer himself hunts	0.162	0.297
Specialist hunters	0.100	**0.112***
Foothold traps	-0.024	0.886
Cage traps	0.141	0.259
Hunting with dogs	0.127	**0.087****
Poison	0.149	0.386

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

In the Logit regression analysis (Table 4.12) a number of variables have a significant effect on the occurrence of large stock predation in the North West province of South Africa. The following socio-economic factors were significant in the Logit model: farm size, completion of school and further studies in agriculture. The significant managerial aspects are: size of breeding herd, calving in May, calving in August, calving in November and age at first conception. The non-lethal significant methods are: guarding dogs; and the lethal significant methods are specialist hunters and hunting with dogs. All these factors have a significant relationship with the occurrence of predation. Interestingly, the two lethal methods, specialist hunters ($p<0.15$) and hunting with dogs ($p<0.10$), as well as the non-lethal method, guarding animals ($p<0.10$), that were found to be significant; all have a positive relationship with the probability of occurrence of predation. Thus, higher probability of occurrence of predation is associated with the use of these respective lethal and non-lethal management methods. The results from the Logit regression in the case, of cattle thus confirm the findings of Van Niekerk (2010) in the case of predation on small livestock. Other factors that are associated with higher probability of occurrence of predation include size of breeding herd ($p<0.15$), and farmers who let their cows calve in May ($p<0.15$) and November ($p<0.15$). The only two management actions that were found to have a negative relationship with the probability of occurrence of predation were: allowing cows to calve in August ($p<0.15$) and waiting for the cows to be relatively older at first conception ($p<0.15$).

4.7.2 Factors that influence the level of predation

The factors that influence the level of predation are those factors that could reduce the level of predation. The variables that have an influence on the level of predation are shown in Table 4.13. Again, by performing the Truncated regression within the PCR framework the significance of individual variables was calculated.

Table 4.13 Results of Truncated regression to identify mitigating factors that affect the level of predation

	Truncated	
Variables	**STD Beta**	**P value**
Socio-economic factors		
Size of farm	0.000	0.966
Farmer's age	-0.001	0.569
Completion of school	-0.001	**0.015*** **
Further studies in agriculture	-0.001	**0.074** **
Member of a farmer's association	0.002	**0.001**** **
Member of a producer's association	0.000	0.313
Experience as a farmer	0.001	0.418
Managerial factors		
Size of breeding herd	0.002	**0.016*** **
Calving in January	0.000	0.466
Calving in February	0.000	**0.002**** **
Calving in March	0.001	0.223
Calving in April	0.000	0.249
Calving in May	0.000	**0.086** **
Calving in June	0.000	0.564
Calving in July	0.000	0.996
Calving in August	-0.001	**0.133* **
Calving in September	0.000	0.820

Calving in October	0.000	**0.075****
Calving in November	0.001	**0.000******
Calving in December	0.000	0.887
Calving on grazing land	0.001	**0.113***
Calving on pastures	-0.001	0.214
Calving on crop residues	0.000	0.789
Calving in the kraal	-0.001	0.382
Times counted per month	0.000	0.919
Times worked with livestock per month	-0.001	**0.030*****
Age at first conception	-0.003	**0.002******
Pregnancy testing	0.000	0.550
Dehorn	0.002	**0.026*****
Removal of dead animals	-0.002	**0.001******
Recording of difficult births	-0.004	**0.007******
Sheep	0.000	0.422
Non-lethal methods		
Herdsmen	0.003	**0.006******
Electric fences	-0.004	**0.002******
Kraaling	-0.002	0.280
Guarding animals	0.000	0.892
Lethal methods		
Farmer himself hunts	0.004	**0.001******
Specialist hunters	0.002	**0.000******
Foothold traps	0.001	0.370
Cage traps	0.003	**0.003******
Hunting with dogs	0.003	**0.000******
Poison	0.003	**0.009******

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

When considering the results from the Truncated regression to assess the factors that affect the level of predation, Table 4.13 shows that there are some actions that are associated with an increase in the level of predation. Only one of the lethal methods and two of the non-lethal methods that were initially hypothesised to influence the level of predation were not found to be significant. All of the significant lethal methods have a positive relationship with the level of predation. As a lethal method the use of cage traps ($p<0.15$) was found to have a positive relationship with the level of predation. Guarding animals ($p<0.15$) as a non-lethal method of prevention, also had a positive relationship with the level of predation. Again, actions that were hypothesised to contribute towards decreased levels of predation were actually found to be associated with higher levels of predation. There are, however, a few factors that have a negative coefficient in the Truncated regression analysis, which suggests that those actions are associated with lower levels of predation. The farmers that completed school ($p<0.10$), farmers who studied further in agriculture ($p<0.10$), farmers who work more frequently with their cows per month ($p<0.10$), farmers who wait for cows to be relatively older at first conception ($p<0.10$), farmers who record difficult births ($p<0.10$) and farmers that use electric fences were found to experience lower levels of predation. It is worth noting that these three actions imply that farmers who are more frequently among their animals suffer lower levels of predation. It thus may be an indication that farmers should regularly visit the animals to decrease the levels of predation.

It is noteworthy that the variables found to be significant in the Logit and Truncated models are not the same. The findings from this study for cattle support the conclusion of Van Niekerk (2010), namely factors that affect the occurrence of predation and factors that affect the level of predation are not the same for sheep and goats.

The signs of the coefficients in the regression analyses reported in Tables 4.12 and 4.13 suggest that farmers should refrain from using lethal and non-lethal management methods to control predation among their cattle, and also that farmers should visit their animals on a regular basis. However, the regression results do not allow for such conclusions to be drawn. While the regression results show the significant relationships between some actions and predation, they do not give information regarding the direction of causality. Thus, the results cannot prove that farmers who stop or reduce their use of lethal and non-lethal management methods will now face less predation. Causality tests are necessary to statistically test whether a change in the use of such management methods will cause a change in the probability of occurrence and/or the level of predation among cattle.

4.7.3 The Granger Causality test

The results in Table 4.14 shows for Granger Causality tests of the actions that were identified to be significant in the Logit regression, and hence to be associated with changes in the occurrence of predation.

Table 4.14 Pairwise Granger Causality tests of significant variables from Logit regression

Null Hypothesis	**Probability (Logit)**
Size of farm does not Granger Cause predation	0.5088
Completion of school does not Granger Cause predation	0.7223
Further studies in agriculture do not Granger Cause predation	0.7589
Size of breeding herd does not Granger Cause predation	0.4227
Calving in May does not Granger Cause predation	0.8049
Calving in August does not Granger Cause predation	0.8774
Calving in November does not Granger Cause predation	0.51057
Age at first conception does not Granger Cause predation	0.1869
Guarding animals do not Granger Cause predation	0.2608
Specialist hunters do not Granger Cause predation	0.6931
Hunting with dogs does not Granger Cause predation	0.2015

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

As shown in Table 4.14 none of the variables that were significant in Table 4.12 (Logit model) is significant in the Granger Causality test. The results from Table 4.14 thus indicate that although some factors were associated with changes in the occurrence of predation in the PCR (Logit) they in fact do not have a significant causal effect on the probability of occurrence of predation. So, although there are significant relationships, the probability of the occurrence of predation will not change if the action is changed. Thus, recommendations merely based on the results from the regression analysis would not necessarily yield in a reduction in the occurrence of predation.

The results from the Grange Causality tests of the actions that were identified to be significant in the Truncated regression, and hence to be associated with changes in the levels of predation are shown in Table 4.15.

Table 4.15 Pairwise Granger Causality tests of significant variables from Truncated regression

Null Hypothesis	**Probability (Truncated)**
Completion of school does not Granger Cause predation	0.151
Further studies in agriculture do not Granger Cause predation	0.224
Member of a farmer's association does not Granger Cause predation	0.703
Size of breeding herd does not Granger Cause predation	0.631
Calving in February does not Granger Cause predation	0.188
Calving in May does not Granger Cause predation	0.719
Calving in August does not Granger Cause predation	0.837
Calving in October does not Granger Cause predation	0.223
Calving in November does not Granger Cause predation	0.980
Calving on grazing land does not Granger Cause predation	0.236
Times worked with livestock per month does not Granger Cause predation	0.231
Age at first conception does not Granger Cause predation	0.327
Dehorning does not Granger Cause predation	0.392
Removal of dead animals does not Granger Cause predation	0.398
Recording difficult births does not Granger Cause predation	0.422
Herdsmen do not Granger Cause predation	0.513
Electric fences do not Granger Cause predation	0.850
Guarding animals do not Granger Cause predation	0.567
Farmer hunts predators does not Granger Cause predation	0.280
Specialist hunters do not Granger Cause predation	0.627
Cage traps do not Granger Cause predation	**0.121***

Hunting with dogs does not Granger Cause predation	**0.067****
Poison does not Granger Cause predation	0.450

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Similar to the findings in Table 4.14, Table 4.15 indicates that not all the significant variables from the Truncated regression analysis actually cause significant changes in the level of predation. For instance, the completion of school does not Granger Cause predation (0.151), but it was significant in the Truncated regression model (0.015). Only hunting with dogs and the use of cage traps were found to significantly Granger Cause and could change the level of predation. Thus, while a number of actions are significantly associated with changes in levels of predation, only two actually cause the change in the level of predation. The Granger Causality test combined with the Truncated model confirmed that use of cage traps and hunting with dogs has a positive causal effect on the level of predation. Cage traps ($p < 0.15$) and hunting with dogs ($p < 0.15$) has a positive effect on predation illustrating that the more the farmers hunt animals that are not problem causing with dogs the higher the level of predation will be. The results from the Truncated regression analysis and the Granger causality test thus suggest that farmers should not kill predators if there is no problem of predation on their farms. Similarly, they should also refrain from using cage traps if there is no predation on their farms.

The "vacuum" effect for small livestock that was described by Snow (2006) is also applicable in the large livestock industry and may be the main reason why the variables that have an effect on the occurrence of predation and on the level of predation differ. The results from the research thus confirm the findings of Snow (2006), that predation could increase if hunting with dog packs were not used correctly. The data suggest that the level of predation will increase if dogs were used to kill predators.

Chapter 5
Conclusions and Recommendations

5.1 Introduction

The impact of predators in the North West province is experienced by all the livestock producers. Predators have a large financial impact on the cattle industry in the North West province and farmers are trying to identify best management practices to reduce predation. There is relatively little quantitative information available on predation in South Africa, especially on cattle predation. This study contributed to previous studies on predation and opened the field for more studies on cattle predation.

This report is part of a larger study that included seven of the nine provinces in South Africa. the North West province was explored in greater detail in this report and data for the other six provinces are presented in **appendices**.

5.2 Meeting the objectives of this study

The objectives of this study were to quantify the direct and indirect costs of predation on cattle, to explore the underlying structures of management measures to control predation, exploring the factors that influence predation and determining the best management practices to be able to advise cattle farmers how to reduce the occurrence of predation and also the level of predation.

5.2.1 Quantifying the direct and indirect costs of predation

The direct cost of predation includes all the direct losses due to predation. This cost is associated with losses of cattle due to predation. The cost is calculated by multiplying the number of cattle lost by the value of the animals; the latter value was provided by the National Stock Theft Forum (2012).

The direct cost of predation and also the percentage losses in the different magisterial districts are shown in Table 5.1. The Bojanala Platinum district reported the largest percentage of losses in the North West province. This district therefore needs the most attention regarding predation management. The Bophirima district has the largest direct cost of the four districts, but this is due to the large population of cattle in the district and not the percentage of predation. Therefore, the districts with the largest percentage predation should be assisted as a high priority. The farmers in the Southern district have the lowest predation losses and the lowest cost, maybe because they are applying the right management practices or there are fewer predators.

Table 5.1 Direct cost of predation in the North West province

Magisterial districts	Average predation losses (%)	Unit cost per animal (ZAR)	Cost of predation (ZAR)
Bojanala Platinum	1.03	10 400	19 739 200
Ngaka Modiri Molema	0.40	10 400	10 524 800
Bophirima	0.59	10 400	27 279 200
Southern	0.29	10 400	10 233 600
Total			**67 776 800**

The total costs of the four districts in the North West province for the lethal and non-lethal management of predation are shown in Table 5.2. The Bophirima district spent the most (ZAR 19.96/head) and the Southern district spent the least (ZAR 8.22/head) on controlling predation. The Southern district is spending little money on controlling predation and has the smallest percentage of predation. This is suggesting that predator numbers are lower in the district, but it may also mean that the farmers are using the right management methods. According to Tables 5.1 and 5.2 it is recommended that the Bophirima district should reduce predation control methods or should use the methods more efficiently. The Bophirima district spent ZAR 26.66/head on predation control and had a 0.59% predation, while the Ngaka Modiri Molema district spent only ZAR 16.59/head and had only 0.40% predation.

The total economic value of predation losses to farmers in the North West province is ZAR 84 319 786, comprising the ZAR 67 776 800 (Table 5.1) for directs costs and the ZAR 16 542 986 (Table 5.2) for the indirect costs of predation management. If farmers could have used this money to buy cattle, they might have bought 8 108 head of cattle (ZAR 10 400 unit cost per animal**)**. This would have had a positive effect on the domestic beef supply and also on the need for importing beef. This would also have a positive effect on the Gross Farm Income (GFI) of South Africa.

Table 5.2 The indirect cost of predation in the North West province

Magisterial districts	Non-lethal cost per unit (ZAR/head)	Total non-lethal cost (ZAR)	Lethal cost per unit (ZAR/head)	Total lethal cost (ZAR)	Total cost of predation (ZAR)
Bojanala Platinum	2.24	412 778	7.25	1 336 001	1 748 779
Ngaka Modiri Molema	5.13	1 297 916	7.23	1 829 226	3 127 142
Bophirima	13.26	5 896 377	6.70	2 979 316	8 875 693
Southern	4.36	1 480 582	3.86	1 310 790	2 791 372
Total		**9 087 653**		**7 455 333**	**16 542 986**

The study has shown that predation has a large impact on the cattle industry in the North West province. The total loss of ZAR 84 million was reported in one year in the cattle sector in the North West province. The study also succeeded in calculating the indirect cost of predation in the province, but there are more indirect costs that should have been added in future, for instance, replacement of killed animals and also interest on killed animals.

This study is the first study that provided information on the total cost of predation on cattle in South Africa. It has been reported by farmers that predation has a large impact on cattle in South Africa, but to date it has not yet been proven on a large scale. This study will help farmers and producer organisations to formulate and justify a case to the government. Farmers and producer organisations will now have information to justify to government the extent and cost of cattle predation. This may convince government that farmers need help with the management of predation and that they may be losing the challenge with predators.

5.2.2 Exploring the underlying structures in predation management practices

The investigation of the underlying structures in predation management practices in the North West province may help us to understand the current behaviour of farmers regarding predation. The objective was met by doing a factor analysis of all the variables that farmers use in the province. This was done to reduce the number of variables to a manageable size.

The results from the factor analysis grouped eight (8) principal components (PCs) from all the variables.

The first PC was calving throughout the year without a structured calving season. This shows that farmers do not have certainty over when cattle are calving and which cattle are pregnant and which are not. This makes it difficult for farmers to pinpoint whether predation is occurring or whether there are problems with conception. Some of the farmers may think it is caused by predators and start hunting non-problem causing animals; farmers may also think conception is low, while in reality it is attributable to predation and the farmer does not realise it. Year round calving could also be favourable towards predators, because there are small calves all year that make easy targets.

The second PC was the farms with a specific calving season in the summer. These farms had a mating season of three months from November to end of January to ensure that the cows would calve in September, October and November. These farmers had more control over their cattle, in the sense that they know that the cattle should all calve in three months time. During this time farmers spend more time counting and observing the animals. This is also the breeding season for black-backed jackal. At the time when the young jackals are learning to hunt, the calves have grown and are able to escape some of the predators.

The third PC has to do with management (pregnancy testing, dehorning, size of breeding herd). These managerial aspects help farmers to have control over animals and help to reduce predation and to prevent predators being blamed for lower rate of conception. The other PCs have to do with predation and reducing the level of predation.

This shows that the objective of exploring the underlying structures in predation management practices in the North West province has been met and that farmers do have underlying structures to help in reducing the impact of predation. Some of the practices show that farmers are trying to control the level of predation and other practices show that some farmers need to apply more management on their farms to reduce predation. This objective helps to understand how farmers operate in the North West province and will assist with making practical and meaningful recommendations.

5.2.3 Exploring the factors that influence predation in the North West province

This objective to explore the factors that influence predation in the North West province will help to identify management approaches that are associated with less predation. These factors will help understanding which variables contribute to the occurrence of predation and also to the level of predation.

The study found that there are 11 variables that are significantly associated with the probability of occurrence of predation and 10 variables that are significantly associated with the probability of changing the level of predation. Moreover, the results show that factors that affect the occurrence of predation and factors that affect the level of predation are not the same. Thus, the results from this study concur with the results by Van Niekerk (2010) who has reported for predation on sheep and goats. The factors that are significantly associated with the probability of occurrence of predation and the level of predation could not be used to determine if the factors are positively or negatively correlated with predation. The results from the PCR could not be used to make recommendation to farmers on how to reduce the occurrence of predation or the level of predation in the province, because they do not give information on direction of causality. Therefore, it was necessary to use the Granger Causality test to determine which of those factors in the PCR could reduce predation.

Thus, while the regression analyses identified a number of factors that are significantly associated with the probability of occurrence of predation and the level of predation, the research failed to identify actions that can be recommended to cattle farmers as best management practices to mitigate predation.

The study illustrated the importance of causality tests to ensure that the recommendations that are made for changes will really bring about the anticipated reduction in predation.

The causality tests showed that there are no actions that significantly caused a change in the probability of occurrence of predation, while only two variables (the use of cage traps and hunting with dogs) significantly caused a change in the level of predation. Thus, despite the number of significant variables from the regression analyses, the only recommendation that can actually be made from this research to mitigate predation is to decrease the use of hunting with dogs and cage traps. This was an unexpected result, but this effect may be because some farmers kill predators that do not cause problems, thereby causing a "vacuum" effect and allow new predators to move in. This unexpected result can also be explained by the number of farmers who do not use any predation management methods. It was illustrated that only 37% of the farmers in the North West province are using any predation management methods, whereas the majority (63%) are not using any. Because of the small percentage of management, this creates a "vacuum" effect. This is not a recommendation that those farmers should stop using predation management methods too, but rather that farmers should coordinate and start collective predation management activities to reduce the predation problem. If only 37% of the farmers are going to use predation management methods the problem will just grow larger because of the "vacuum" effect, but if farmers start with coordinated predation management they could have a positive impact on the vacuum effect.

The results indicated that there were no best management practices that could be identified from these analyses. The third objective showed the importance of the Granger Causality test to determine the factors that must be handled to reduce predation. More research, however, is necessary to identify best management practices that can be recommended to cattle farmers to mitigate predation in the North West province.

5.3 Limitations in this study

A limitation of this study is that it was not possible to identify best management practices in the North West province. This may be a result of farmers who did not complete the survey openly, because they were frightened that information would be leaked to organisations that protect predators. One of the possible solutions could be to sample a smaller area in the North

West province and do a face-to-face follow-up interview with the farmers to see if they would supply more detailed information. The second solution may be to sample a smaller area in the North West province and provide some new best management practices and monitor whether there are any changes in the occurrence or level of predation.

5.4 Recommendations

Based on the findings from this study it is recommended that farmers should use predation management methods in the correct manner and also that more farmers should start working together in a coordinated manner. Farmers should not hunt with dogs, nor use cage traps if there is little or zero predation on the farm, specifically if the rest (63%) of the farmers in the North West province don't start using predation management methods. Some farmers use hunting with dogs and cage traps to prevent predation, but instead they kill predators that do not cause harm to livestock and so create a "vacuum" effect for other predators to move in.

It is also evident that a coordinated strategy to manage predation in the province and also in South Africa should be established. This need not necessarily be done by the government or producer organisations, but the unit could be as small as a farmer's organisation. It would help if the government could work closely with the livestock producers and also with the livestock organisations to coordinate the management of predation. The government could provide funds to producer organisations, which could train farmers in the management of predation. The producers will still have the primary responsibility for managing predation on the farms, but the policy makers could change the legislation to protect the farmers. The government and the producer organisations must help the farmers by funding personnel to assist farmers to identify the specific cause of death of animals that died. This will help farmers to apply correct management strategies, knowing the correct causes of death and will also deter farmers from killing predators that do not kill livestock and thereby preventing the "vacuum" effect and allow other predators to move in.

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Appendix B: Eastern Cape

The primary information obtained in the survey from **119 responding farmers** in the Eastern Cape province.

Table: Number of farmers surveyed, land utilisation and cattle numbers in the Eastern Cape

	Surveyed	Eastern Cape	Percentage
Farmers	119	4 640	2.6
Head of cattle	70 911	611 242	11.6
Grazing land (ha)	511 601	13 644 822	3.7

Source: NDA, 2012

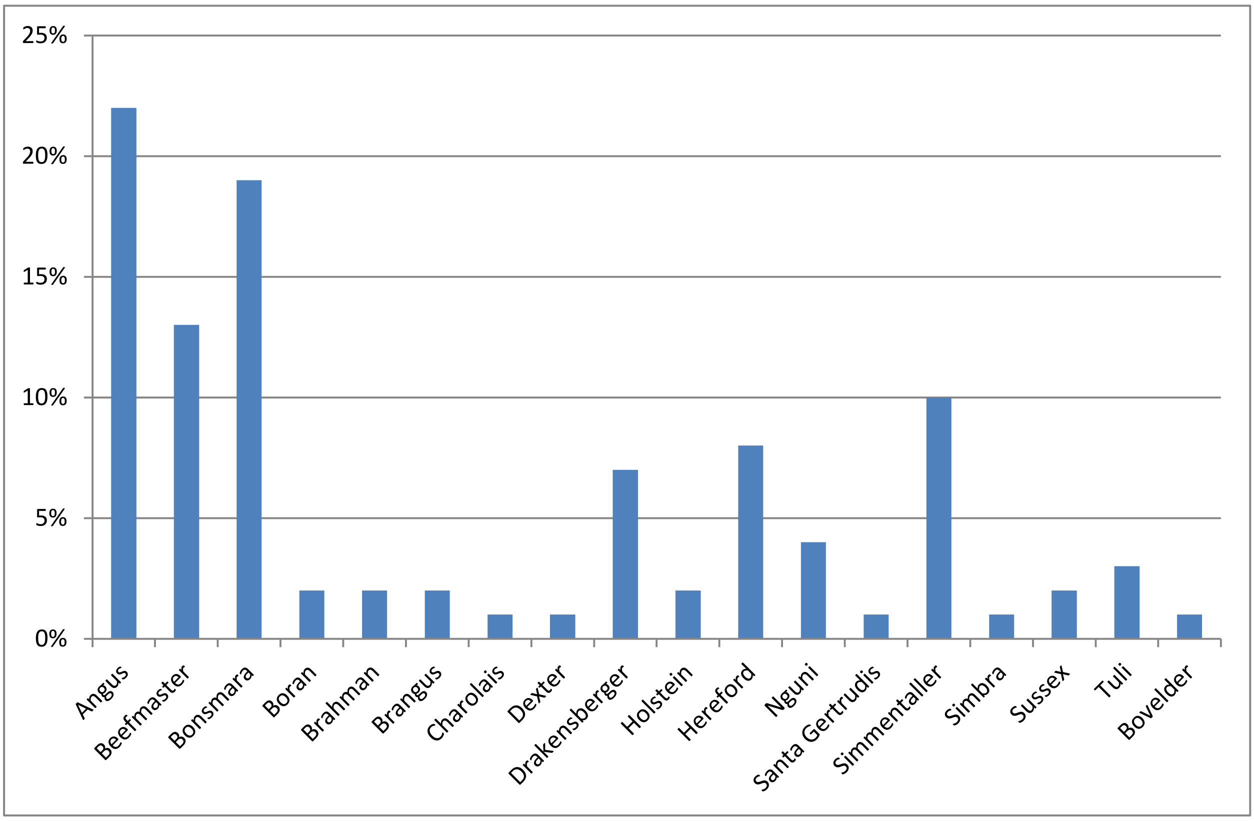

Figure: Cattle breeds of respondents surveyed in the Eastern Cape province.

Table: Farmers personal information in the North West province

Survey information	
Farmers average age (years)	50
Completion of school	62%
Further studies in agriculture	41%
Members of a farmer association	97%
Member of a producers association	93%
Experience as farmer (years)	25

Table: The number of cattle lost to predation in the Eastern Cape

Magisterial districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
Cacadu	0	3 794	0
Amathole	26	24 413	0.11
Chris Hani	15	27 134	0.06
Ukhahlamba	3	15 570	0.02
Total	44	70 911	-

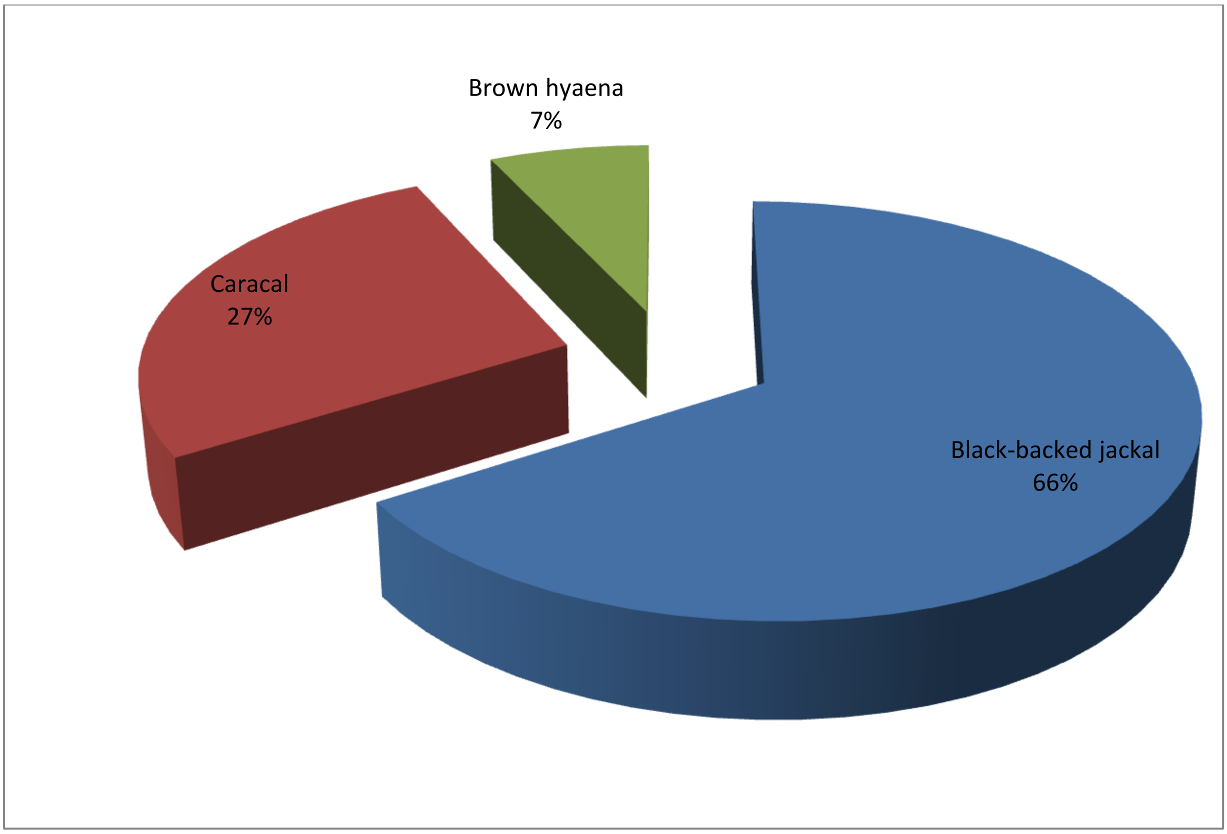

Figure: Predator species responsible for predation losses in the Eastern Cape.

Table: The direct cost of predation on cattle in the Eastern Cape

Magisterial district	Number of cattle in the Eastern Cape	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
Cacadu	24 890	0	0	10 400	0
Amathole	231 679	0.11	247	10 400	2 568 800
Chris Hani	209 588	0.06	116	10 400	1 206 400
Ukhahlamba	145 085	0.02	28	10 400	291 200
Total	611 242	-	391	-	4 066 400

Table: Costs of lethal predation management in the Eastern Cape

Magisterial district	Total lethal cost in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
Cacadu	0	3 794	0	24 890	0
Amathole	15 000	24 413	0.61	231 679	142 345
Chris Hani	12 500	27 134	0.46	209 588	96 552
Ukhahlamba	0	15 570	0	145 085	0
Total	27 500	70 911	-	611 242	238 897

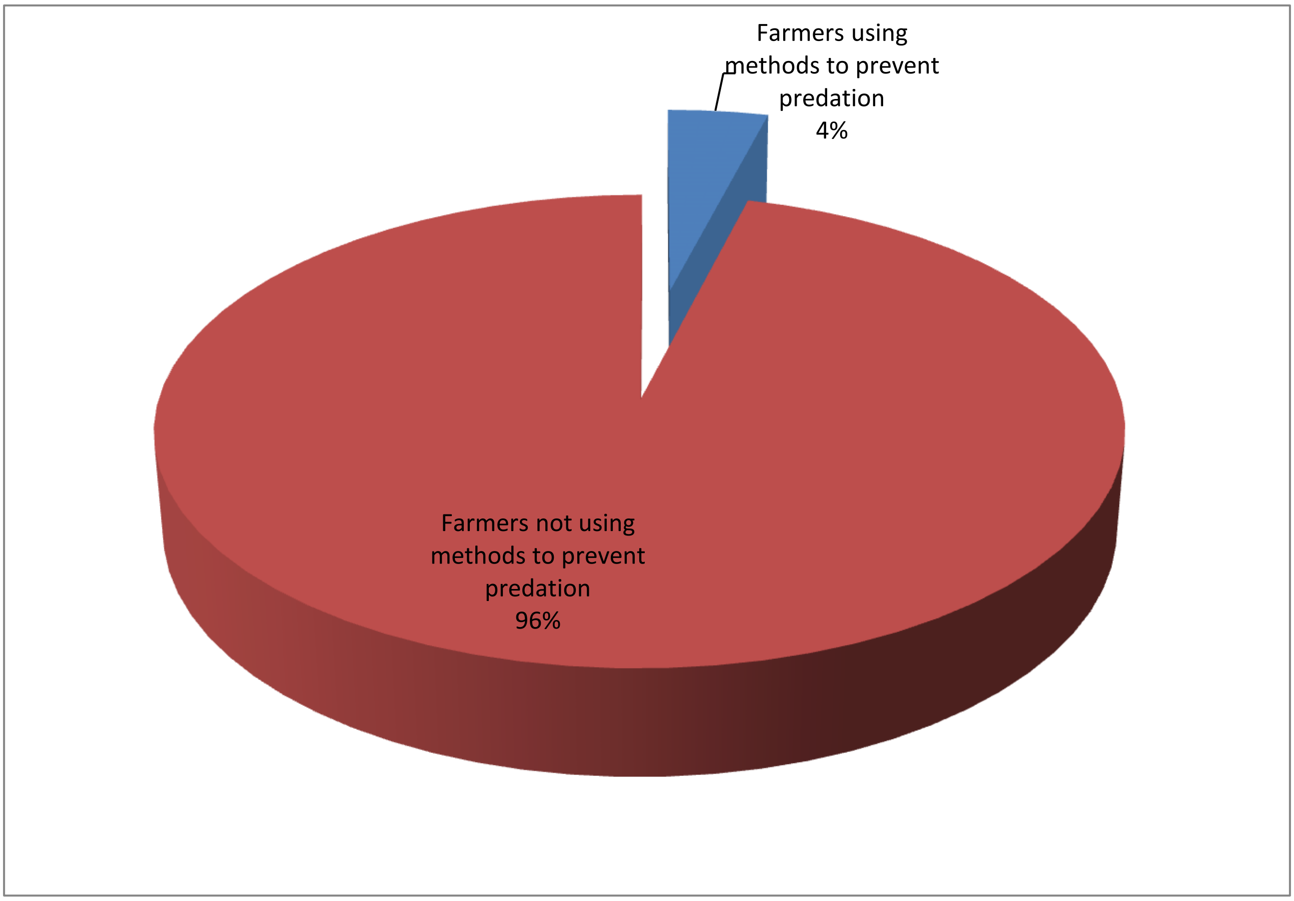

Figure: Percentage of farmers using predation management methods in the Eastern Cape.

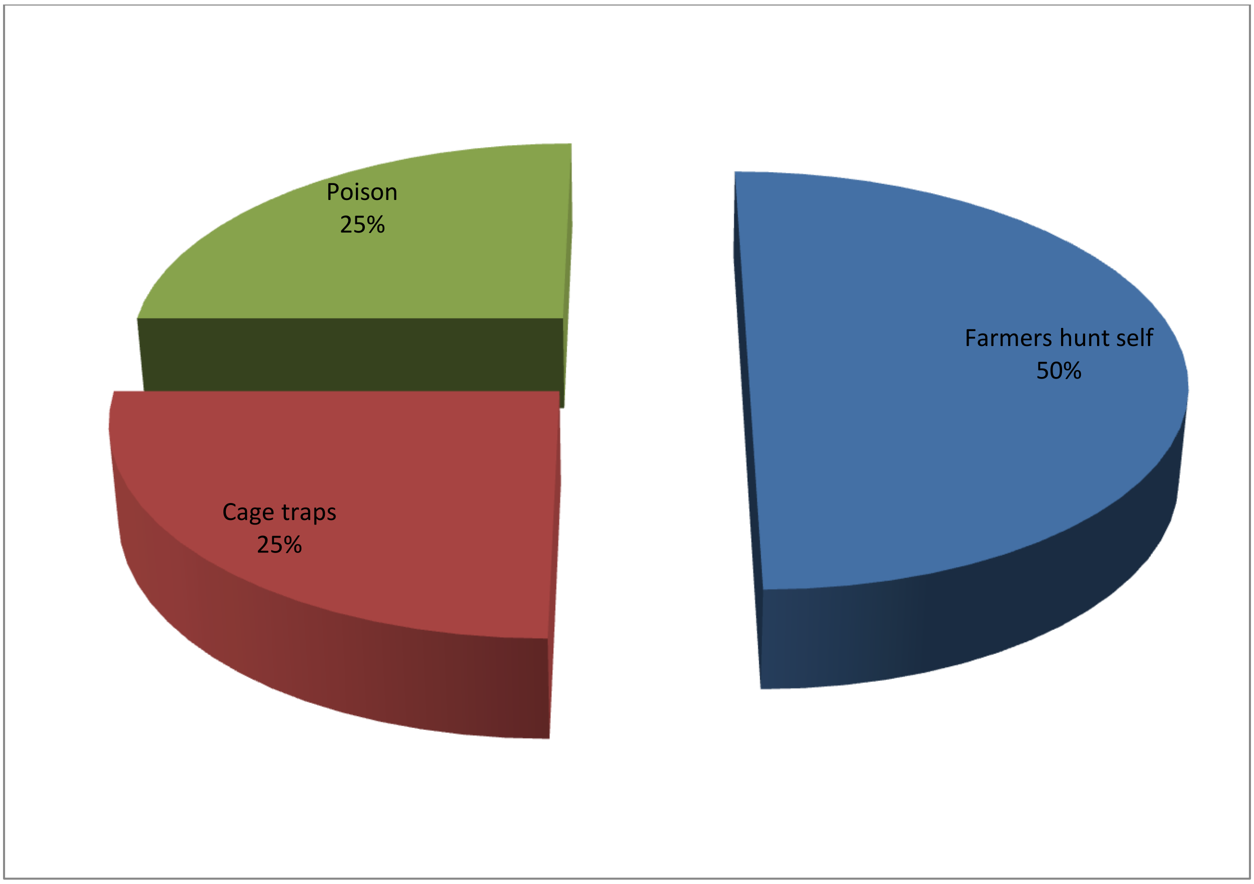

Figure: Percentage use of lethal methods in the Eastern Cape.

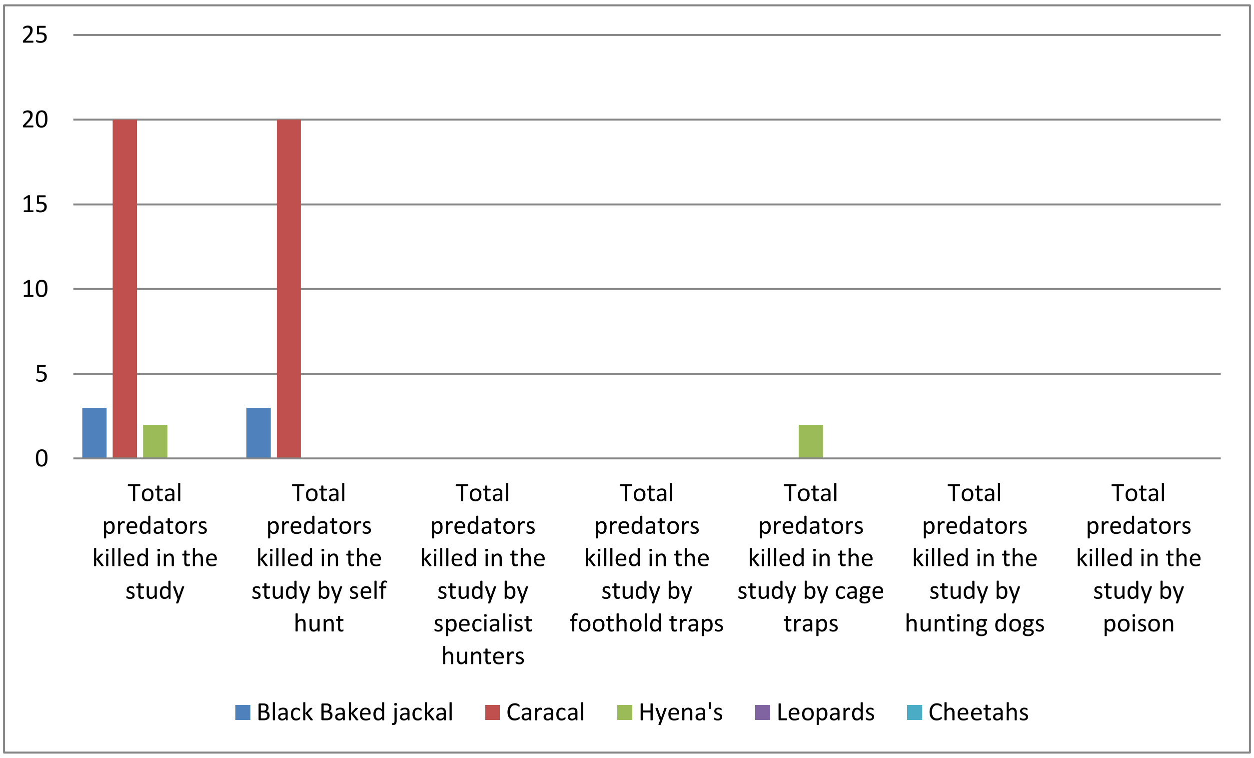

Figure: Number of predators killed with lethal methods in the Eastern Cape.

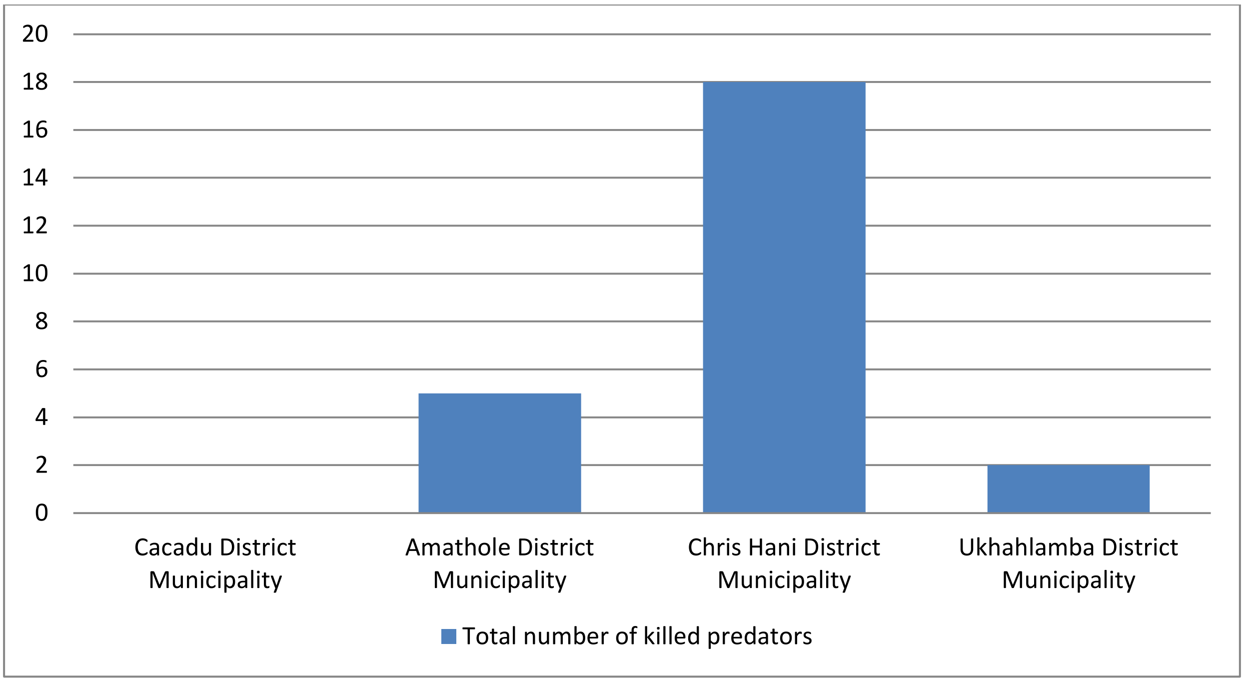

Figure: Total number of predators killed with lethal methods in the Eastern Cape.

Table: The cost of non-lethal predation management in the Eastern Cape

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
Cacadu	0	3 794	0	24 890	0
Amathole	20 000	24 413	0.82	231 679	189 800
Chris Hani	43 000	27 134	1.58	209 588	332 140
Ukhahlamba	0	15 570	0	145 085	0
Total	63 000	70 911	-	611 242	521 940

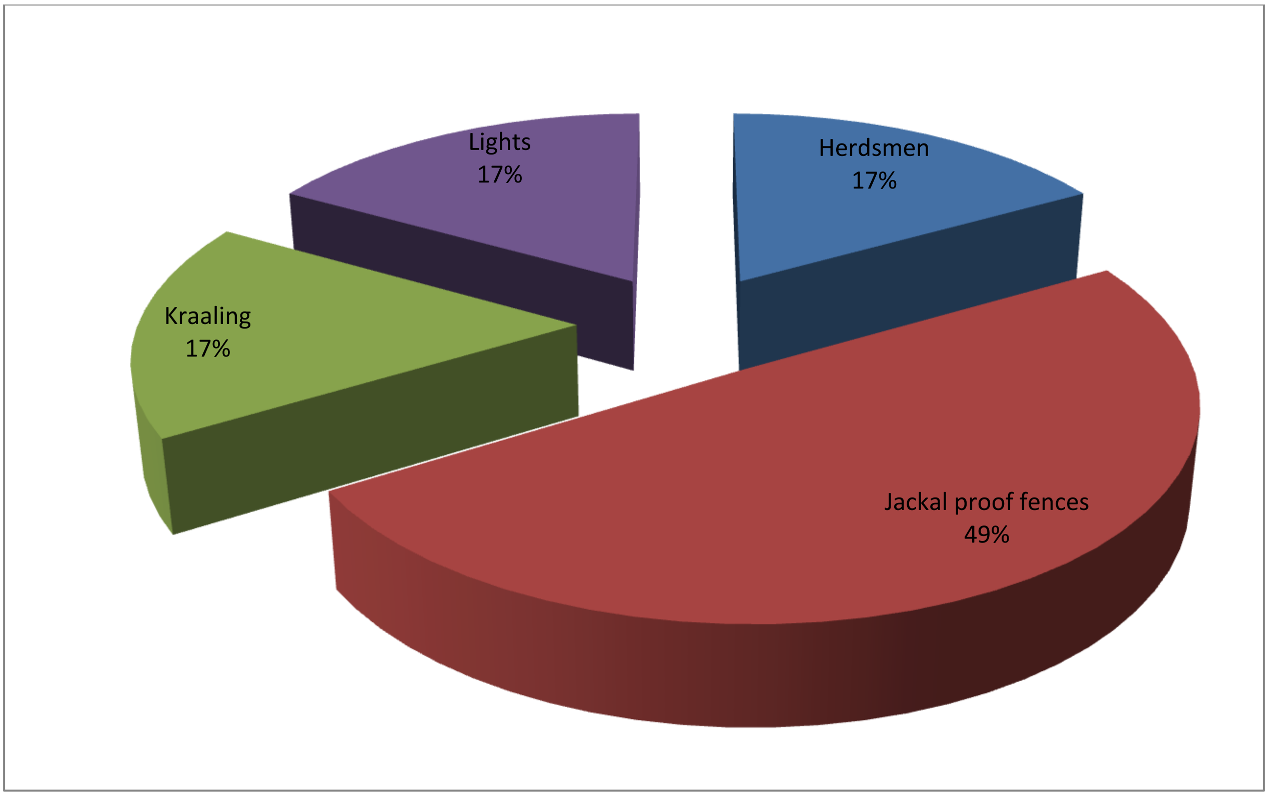

Figure: Percentage use of non-lethal methods to prevent predation in the Eastern Cape.

Table: The total direct and indirect cost of predation in the Eastern Cape

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost
Cacadu	0	0	0	0
Amathole	142 345	189 800	2 568 800	2 900 945
Chris Hani	96 552	332 140	1 206 400	1 635 092
Ukhahlamba	0	0	291 200	291 200
Total	238 897	521 940	4 066 400	4 827 237

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.777
Bartlett's Test of Sphericity	Approx.Chi-Square	1893.545
	df	190
	Sig.	0.000

Table: Results of the Communalities

	Initial	Extraction
Calving in January	1.000	0.685
Calving in February	1.000	0.801
Calving in March	1.000	0.817
Calving in April	1.000	0.827
Calving in May	1.000	0.817
Calving in June	1.000	0.782
Calving in July	1.000	0.807
Calving in August	1.000	0.665
Calving in September	1.000	0.778
Calving in November	1.000	0.807
Calving in December	1.000	0.775
Calving on grazing land	1.000	0.744
Calving on pastures	1.000	0.806
Age at first conception	1.000	0.780
Pregnancy testing	1.000	0.611
Dehorn	1.000	0.553

Removal of death animals	1.000	0.741
Difficult birth	1.000	0.511
Sheep	1.000	0.678
Herdsmen	1.000	0.821

Table: Percentage variance explained

	Rotation Sum of Squared Loadings		
Component	Eigen value	% of variance	Cumulative %
1	6.007	30.003	30.033
2	1.815	9.074	39.108
3	1.747	8.734	47.841
4	1.591	7.955	55.796
5	1.370	6.849	62.645
6	1.176	5.881	68.527
7	1.101	5.505	74.032

Table: Results from the Rotated Component Matrix

		Component					
	1	**2**	**3**	**4**	**5**	**6**	**7**
Calving in July	**0.889**	-0.060	0.010	0.104	0.021	-0.021	-0.004
Calving in February	**0.881**	-0.023	0.060	0.102	0.087	-0.044	0.014
Calving in March	**0.881**	0.002	0.152	0.063	0.094	-0.055	0.048

Calving in May	**0.870**	-0.081	0.155	0.102	0.068	-0.118	-0.001
Calving in April	**0.868**	-0.069	0.175	0.095	0.152	-0.060	0.048
Calving in June	**0.863**	-0.095	0.096	0.099	-0.048	-0.081	-0.026
Calving in January	**0.772**	-0.073	-0.054	0.237	-0.139	-0.018	-0.070
Calving in August	**0.654**	-0.105	-0.052	-0.202	0.352	0.236	-0.054
Removal of death animals	0.095	**0.755**	-0.062	-0.112	-0.191	0.024	0.329
Pregnancy testing	-0.340	**0.638**	0.060	0.113	0.151	0.130	-0.178
Difficult birth	-0.074	**0.606**	0.248	0.103	-0.158	-0.155	-0.133
Dehorn	-0.152	**0.558**	-0.297	-0.049	-0.064	0.202	-0.290
Calving on pastures	0.170	0.060	**0.877**	0.037	0.042	0.033	0.021
Calving on grazing land	-0.112	0.013	**-0.845**	0.064	0.047	0.104	0.021
Calving in November	0.137	0.047	-0.045	**0.871**	0.082	0.132	0.030
Calving in December	0.341	-0.002	0.031	**0.777**	-0.212	-0.079	0.045
Calving in September	0.134	-0.028	0.012	-0.095	**0.852**	0.118	-0.103
Sheep	-0.151	-0.292	0.021	-0.100	**-0.545**	0.486	-0.161

Age at first conception	-0.093	0.127	-0.083	0.098	0.100	**0.848**	0.095
Herdsmen	-0.068	-0.100	-0.003	0.061	-0.048	0.063	**0.892**

The results of the Logit and Truncated regression could not been calculated. The reason for this was because of too little predation in the Eastern Cape. The farmers that have been surveyed reported little predation and therefore the model did not run properly. Therefore the results of the Pairwise Granger Causality test will also be excluded.

Appendix C: Free State

The primary information obtained in the survey from **430 responding farmers** in the Free State province.

Table: Number of farmers surveyed, land utilisation and cattle numbers in the Free State province

	Surveyed	Free State	Percentage
Farmers	430	6 065	7.0
Head of cattle	245 983	2 215 042	11
Grazing land (ha)	716 367	7 538 677	9.5

Source: NDA, 2012

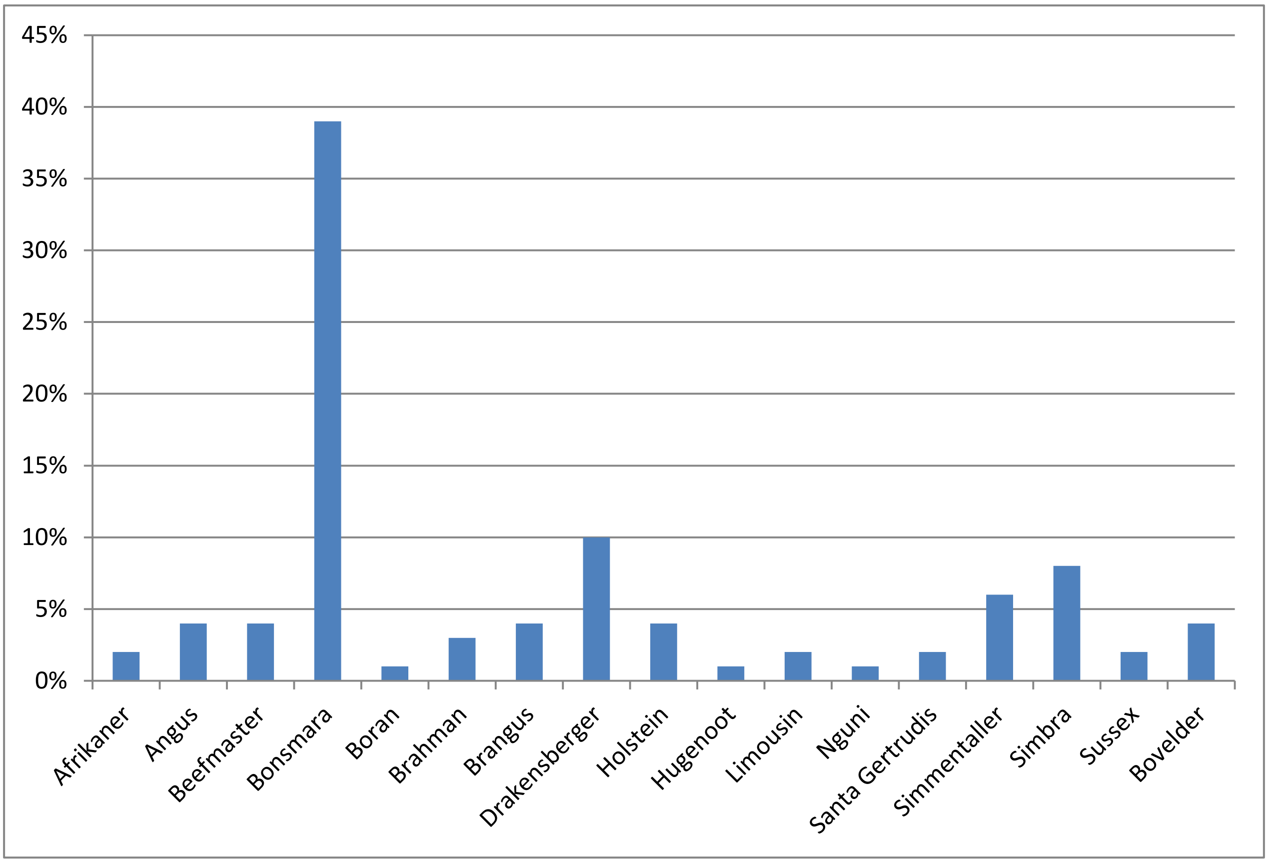

Figure: Cattle breeds of respondents surveyed in the Free State province.

Table: Farmers personal information in the Free State province

Survey information	
Farmers average age (years)	51
Completion of school	53%
Further studies in agriculture	33%
Members of a farmer association	84%
Member of a producers association	86%
Experience as farmer (years)	25

Table: The number of cattle lost to predation in the Free State

Magisterial districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
Xhariep	15	13 395	0.11
Motheo	39	15 588	0.25
Lejweleputswa	139	31 464	0.44
Thabo Mofutsanyane	203	97 622	0.21
Fazile Dabi	236	87 914	0.27
Total	632	245 983	-

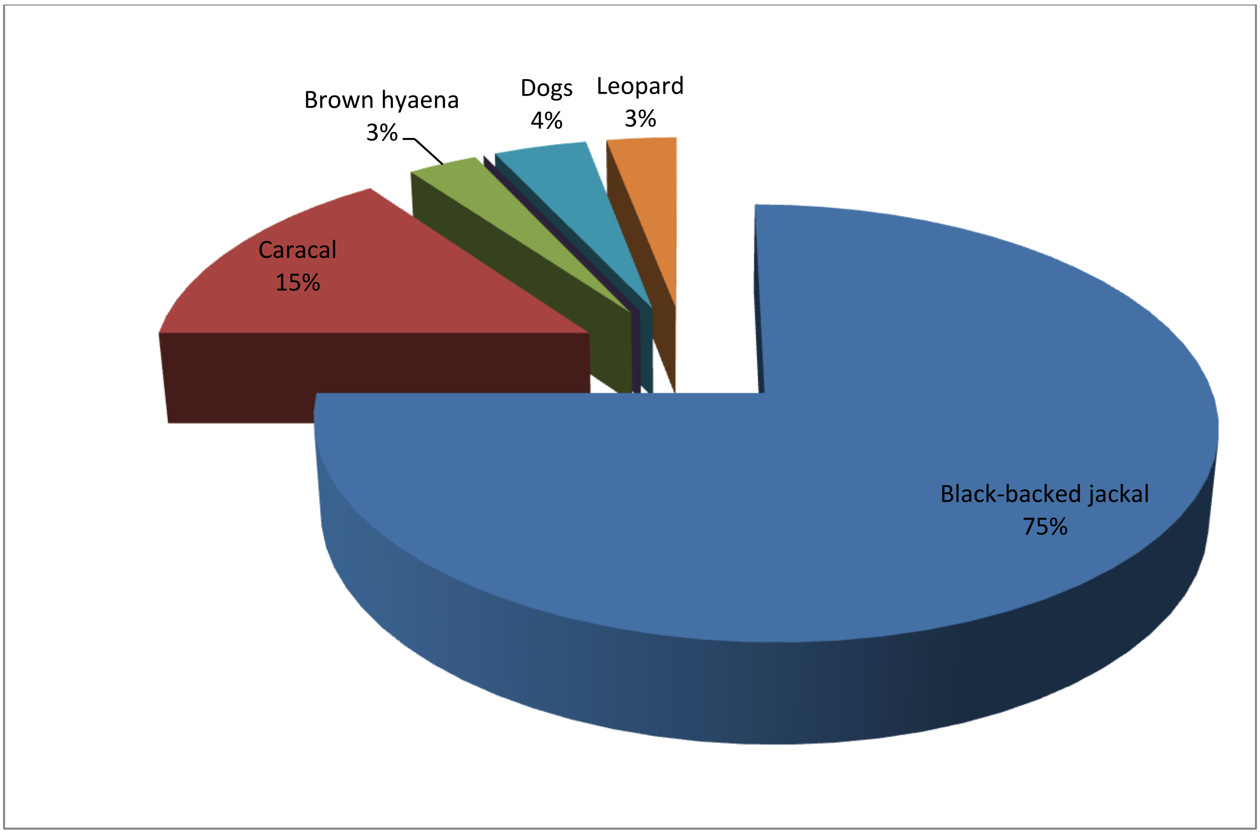

Figure: Predator species responsible for predation losses in the Free State.

Table: The direct cost of predation on cattle in the Free State

Magisterial district	Number of cattle in the Free State	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
Xhariep	186 377	0.11	209	10 400	2 173 600
Motheo	182 886	0.25	458	10 400	4 763 200
Lejweleputswa	446 561	0.44	1973	10 400	20 519 200
Thabo Mofutsanyane	733 372	0.21	1525	10 400	15 860 000
Fazile Dabi	665 846	0.27	1787	10 400	18 584 800
Total	2 215 042	-	5952	-	61 900 800

Table: Costs of lethal predation management in the Free State

Magisterial district	Total lethal cost in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
Xhariep	584 610	13 395	43.64	186 377	8 134 219
Motheo	166 650	15 588	10.69	182 886	1 955 219
Lejweleputswa	271 800	31 464	8.64	446 561	3 857 592
Thabo Mofutsanyane	335 900	97 622	3.44	733 372	2 523 403
Fazile Dabi	293 400	87 914	3.34	665 846	2 222 163
Total	1 652 360	245 983	-	2 215 042	18 692 596

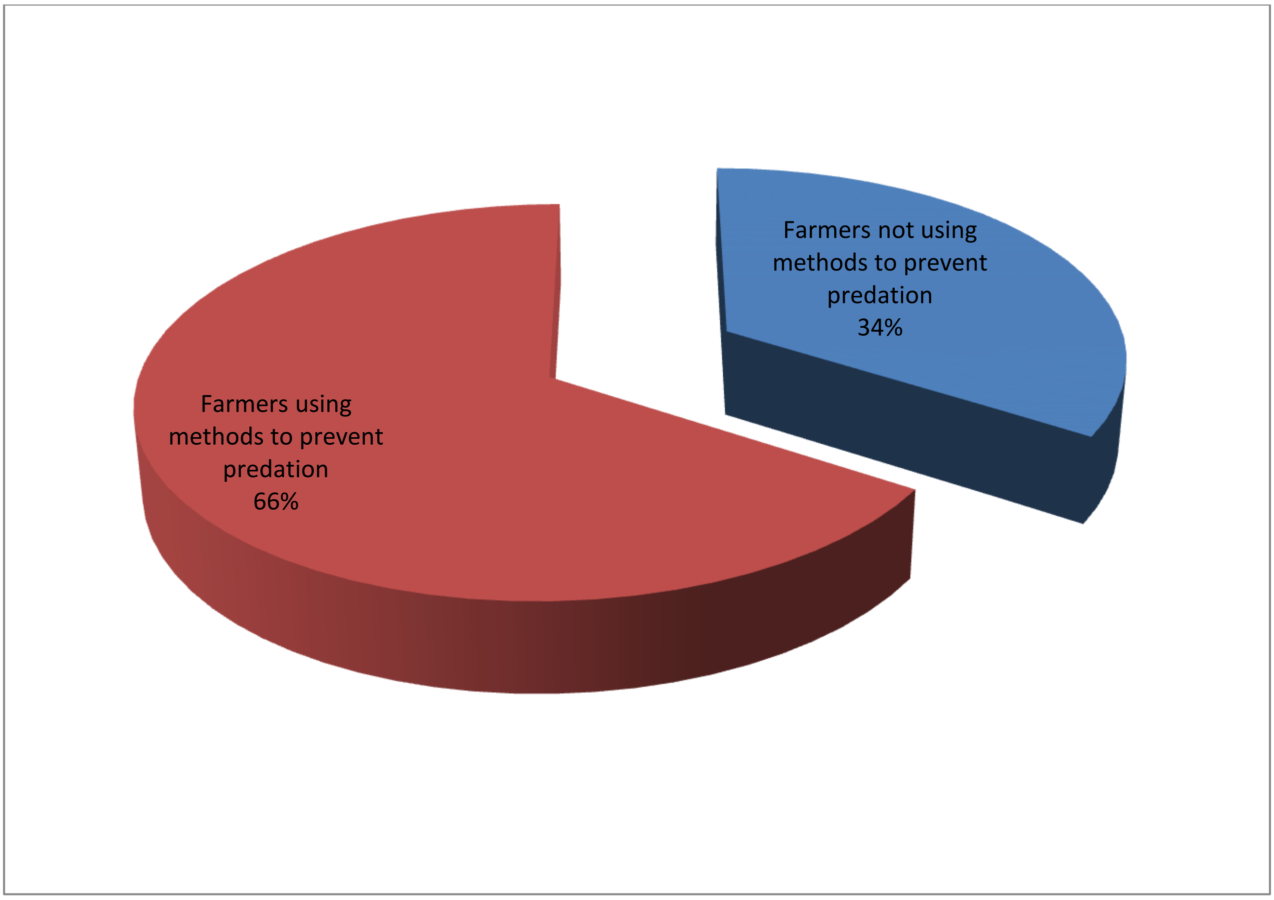

Figure: Percentage of farmers using predation management methods in the Free State.

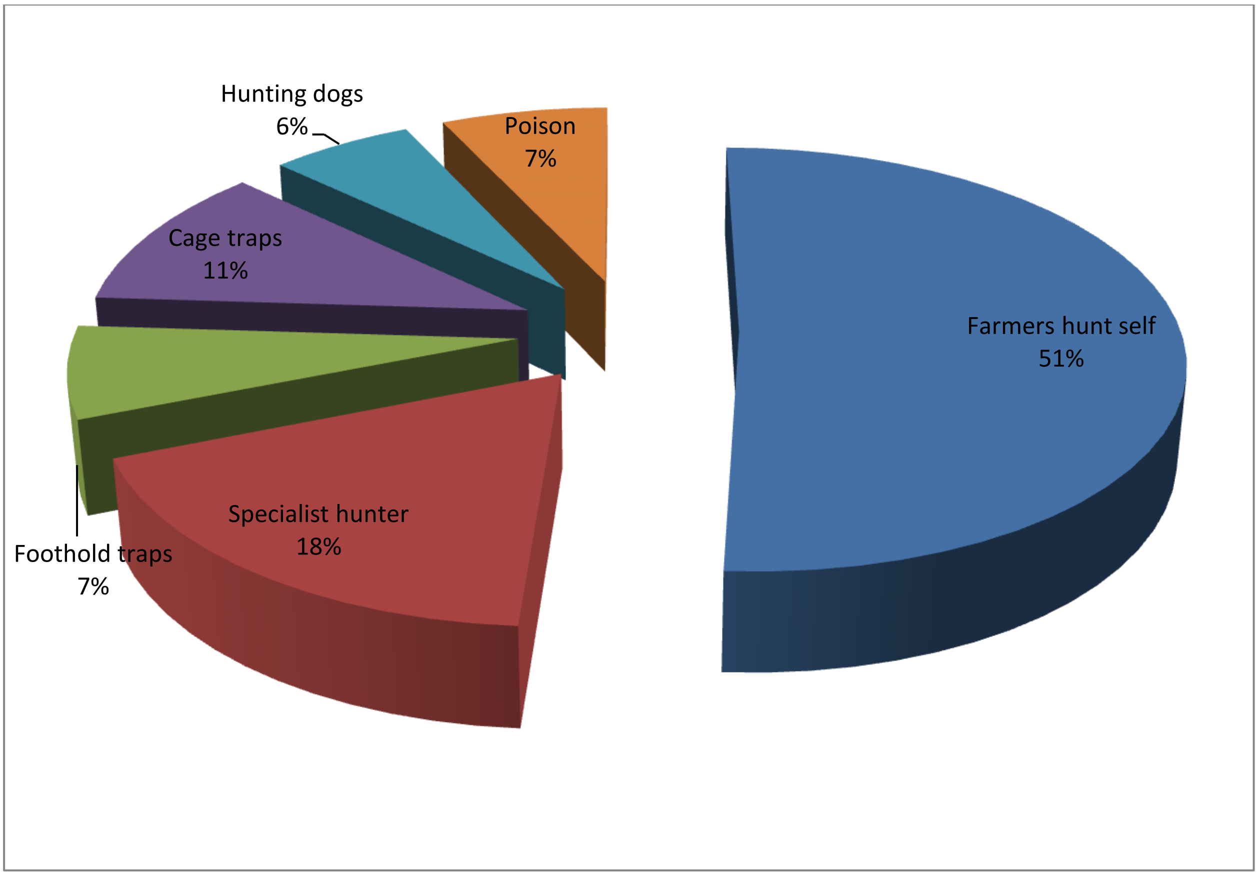

Figure: Percentage use of lethal methods in the Free State.

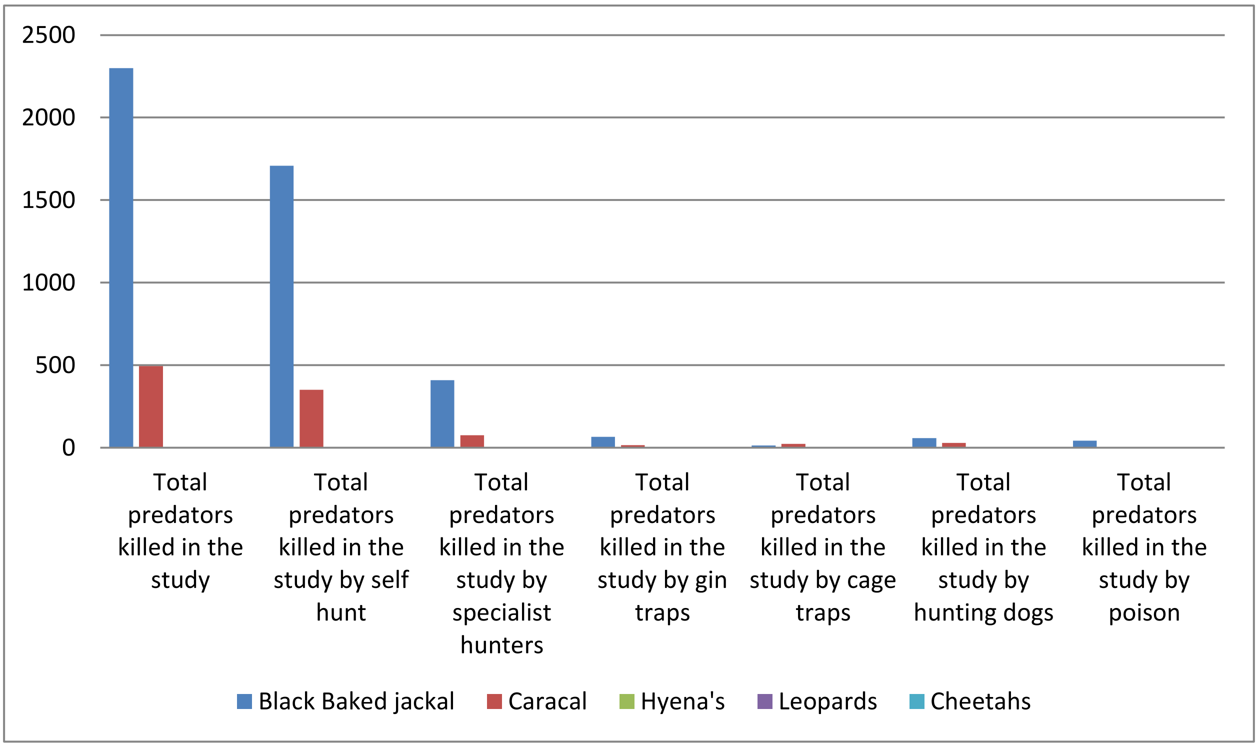

Figure: Number of predators killed with lethal methods in the Free State.

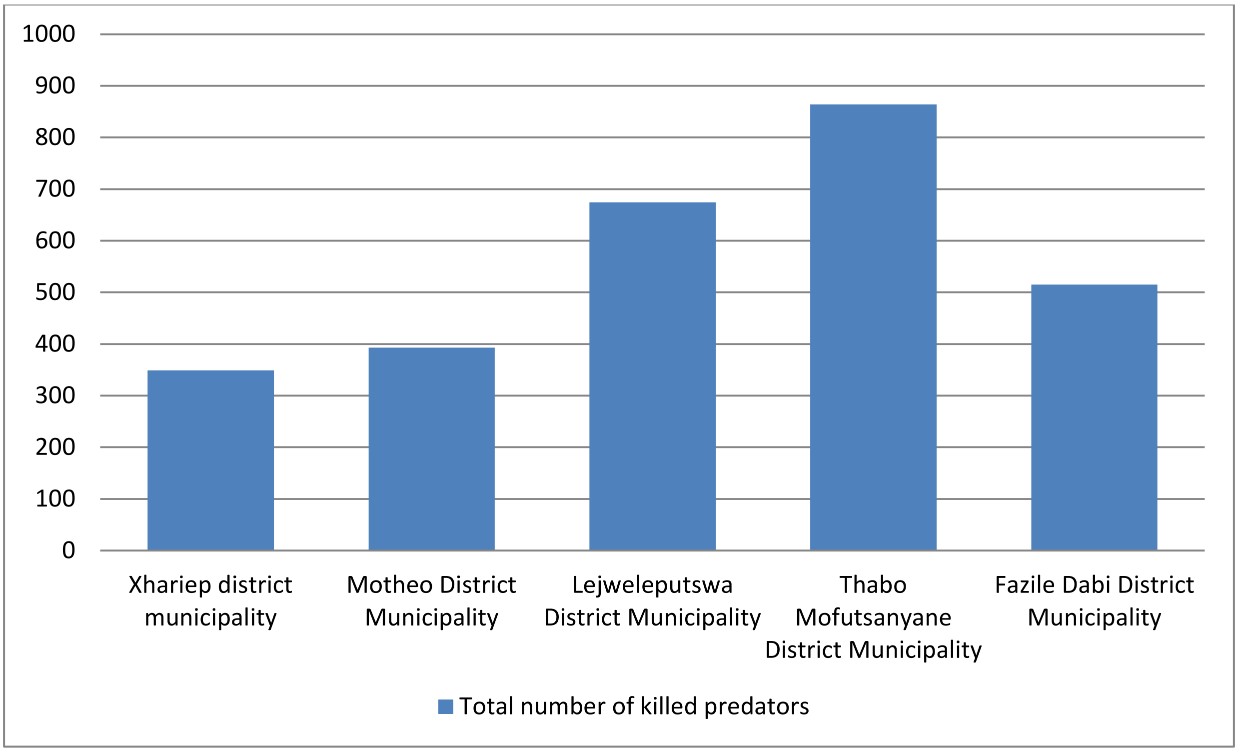

Figure: Total number of predators killed with lethal methods in the Free State.

Table: The cost of non-lethal predation management in the Free State

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
Xhariep	376 780	13 395	28.13	186 377	5 242 487
Motheo	385 400	15 588	24.72	182 886	4 521 700
Lejweleputswa	1 065 291	31 464	33.86	446 561	15 119 419
Thabo Mofutsanyane	530 001	97 622	5.43	733 372	3 981 560
Fazile Dabi	1 075 000	87 914	12.23	665 846	8 141 871
Total	3 432 472	245 983		2 215 042	37 007 037

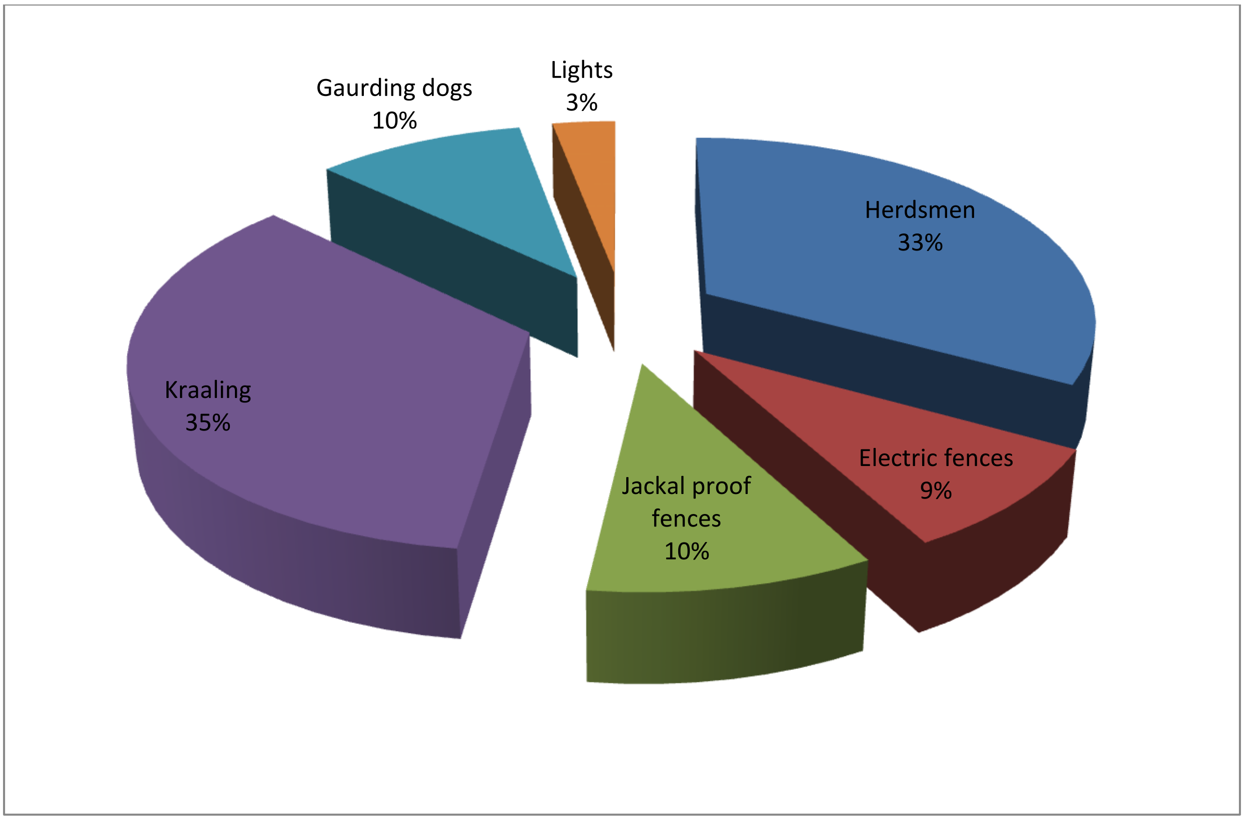

Figure: Percentage use of non-lethal methods to prevent predation in the Free State.

Table: The total direct and indirect cost of predation in the Free State

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost
Xhariep	8 134 219	5 242 487	2 173 600	15 550 306
Motheo	1 955 219	4 521 700	4 763 200	11 240 119
Lejweleputswa	3 857 592	15 119 419	20 519 200	39 496 211
Thabo Mofutsanyane	2 523 403	3 981 560	15 860 000	22 364 963
Fazile Dabi	2 222 163	8 141 871	18 584 800	28 948 834
Total	18 692 596	37 007 037	61 900 800	117 600 433

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.820
Bartlett's Test of Sphericity	Approx.Chi-Square	3479.691
	df	120
	Sig.	0.000

Table: Results of the Communalities

	Initial	Extraction
Size of breeding herd	1.000	0.721
Calving in January	1.000	0.655
Calving in February	1.000	0.781
Calving in March	1.000	0.824
Calving in April	1.000	0.811
Calving in May	1.000	0.815
Calving in June	1.000	0.806
Calving in July	1.000	0.668
Calving in the kraal	1.000	0.725
Times counted per month	1.000	0.613
Times worked with animals per month	1.000	0.699
Pregnancy testing	1.000	0.650
Dehorn	1.000	0.700
Specialist hunter	1.000	0.620
Cage traps	1.000	0.734
Guarding dogs	1.000	0.935

Table: Percentage variance explained

Component	Rotation Sum of Squared Loadings		
	Eigen value	% of variance	Cumulative %
1	5.320	33.250	33.250
2	1.551	9.695	42.945
3	1.482	9.262	52.207
4	1.251	7.819	60.026
5	1.124	7.026	67.052
6	1.037	6.482	73.534

Table: Results from the Rotated Component Matrix

	Component					
	1	**2**	**3**	**4**	**5**	**7**
Calving in March	**0.905**	0.002	0.037	0.030	-0.041	-0.026
Calving in April	**0.895**	-0.021	0.063	-0.044	0.020	-0.062
Calving in May	**0.892**	-0.049	0.087	-0.076	0.003	-0.052
Calving in June	**0.887**	-0.075	0.099	-0.052	0.003	0.029
Calving in February	**0.876**	-0.032	0.018	0.006	-0.091	0.069
Calving in July	**0.802**	-0.084	0.111	-0.059	-0.003	0.052
Calving in January	**0.797**	-0.040	0.013	0.019	-0.104	0.079

Dehorn	-0.043	**0.829**	-0.021	-0.095	-0.024	0.029
Pregnancy testing	-0.154	**0.744**	0.032	0.203	0.174	0.001
Calve in the kraal	0.070	-0.023	**0.834**	-0.018	0.029	0.149
Times worked with animals per month	0.148	0.051	**0.802**	0.003	-0.115	-0.134
Cage traps	-0.034	0.051	-0.137	**0.811**	-0.251	-0.11
Specialist hunter	-0.045	-0.003	0.120	**0.708**	0.319	-0.014
Size of breeding herd	-0.041	0.362	0.012	-0.065	**0.754**	-0.124
Times counted per month	0.105	0.392	0.268	-0.149	**-0.570**	-0.169
Guarding dogs	0.058	0.013	0.019	-0.024	-0.024	**0.964**

Table: Results of Logit regression to identify mitigating factors that affect the occurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	0.135	0.164
Farmer’s age	-0.110	0.201
Completion of school	0.000	0.999
Further studies in agriculture	0.031	0.705

Member of a farmer’s association	0.094	0.292
Member of a producer’s association	0.130	0.135*
Experience as a farmer	-0.064	0.341
Managerial factors		
Sizeof breeding herd	0.132	0.190
Calving in January	-0.005	0.903
Calving in February	-0.008	0.664
Calving in March	0.011	0.572
Calving in April	0.018	0.481
Calving in May	0.017	0.302
Calving in June	0.002	0.790
Calving in July	-0.039	0.274
Calving in August	-0.069	0.387
Calving in September	-0.024	0.820
Calving in October	0.062	0.233
Calving in November	0.116	0.132*
Calving in December	0.031	0.725
Calving on grazing land	-0.110	0.050***
Calving on pastures	0.089	0.075**
Calving on crop residues	0.100	0.166
Calving in the kraal	-0.037	0.522
Times counted per month	0.001	0.983
Times worked with livestock per month	-0041	0.477
Age at first conception	-0.116	0.296
Pregnancy testing	-0.015	0.888
Dehorn	0.053	0.549
Removal of dead animals	0.045	0.402
Recording of difficult births	0.073	0.388
Sheep	0.020	0.785
Non-lethal methods		
Herdsmen	-0.028	0.274
Jackals proof	-0.027	0.336

Electric fences	0.070	0.110*
Lights	0.047	0.192
Kraaling	0.066	0.090**
Guarding animals	0.056	0.581
Lethal methods		
Farmer himself hunts	0.065	0.170
Specialist hunters	-0.064	0.408
Gin traps	-0.065	0.275
Cage traps	-0.045	0.581
Hunting with dogs	0.042	0.630
Poison	0.123	0.070**

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Results of Truncated regression to identify mitigating factors that affect the level of predation

	Truncated	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	0.000	0.510
Farmer's age	0.000	0.321
Completion of school	-0.001	0.122*
Further studies in agriculture	-0.001	0.161
Member of a farmer's association	0.000	0.893
Member of a producer's association	0.000	0.802
Experience as a farmer	0.000	0.277
Managerial factors		
Sizeof breeding herd	0.000	0.496
Calving in January	0.000	0.285
Calving in February	0.000	0.206
Calving in March	0.000	0.455
Calving in April	0.000	0.791
Calving in May	0.000	0.840
Calving in June	0.000	0.057**

Calving in July	0.000	0.090**
Calving in August	-0.001	0.203
Calving in September	0.000	0.430
Calving in October	0.000	0.645
Calving in November	0.000	0.356
Calving in December	0.001	0.241
Calving on grazing land	0.000	0.907
Calving on pastures	0.000	0.328
Calving on crop residues	0.000	0.980
Calving in the kraal	0.000	0.705
Times counted per month	0.000	0.254
Times worked with livestock per month	0.000	0.599
Age at first conception	-0.001	0.386
Pregnancy testing	0.000	0.913
Dehorn	0.000	0.342
Removal of dead animals	0.000	0.934
Record of difficult births	0.000	0.572
Sheep	0.000	0.477
Non-lethal methods		
Herdsmen	0.000	0.854
Jackals proof	0.000	0.223
Electric fences	0.000	0.891
Lights	0.000	0.175
Kraaling	0.000	0.638
Guarding animals	-0.001	0.275
Lethal methods		
Farmer himself hunts	0.000	0.852
Specialist hunters	0.000	0.776
Gin traps	0.001	0.169
Cage traps	0.001	0.126*
Hunting with dogs	-0.001	0.059**
Poison	0.000	0.564

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Pairwise Granger Causality test of significant variables from Logit regression

Null Hypothesis:	Probability (Logit)
Member of a producer's association does not Granger Cause predation	0.547
Calving in November does not Granger Cause predation	0.835
Calving on grazing land does not Granger Cause predation	0.028***
Calving on pastures does not Granger Cause predation	0.013***
Electric fences does not Granger Cause predation	0.872
Kraaling does not Granger Cause predation	0.071**
Poison does not Granger Cause predation	0.105*

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Pairwise Granger Causality test of significant variables from Truncated regression

Null Hypothesis:	Probability (Truncated)
Completion of school does not Granger Cause predation	0.404
Calving in June does not Granger Cause predation	0.833
Calving in July does not Granger Cause predation	0.961
Cage traps does not Granger Cause predation	0.834
Hunting with dogs does not Granger Cause predation	0.201

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Appendix D: KwaZulu-Natal

The primary information obtained in the survey from **202 responding farmers** in KwaZulu-Natal.

Table: Number of farmers surveyed, land utilisation and cattle numbers in KwaZulu-Natal

	Surveyed	KwaZulu-Natal	Percentage
Farmers	202	2 611	7.7
Head of cattle	231 391	1 038 048	22.3
Grazing land (ha)	527 068	5 329 640	9.9

Source: NDA, 2012

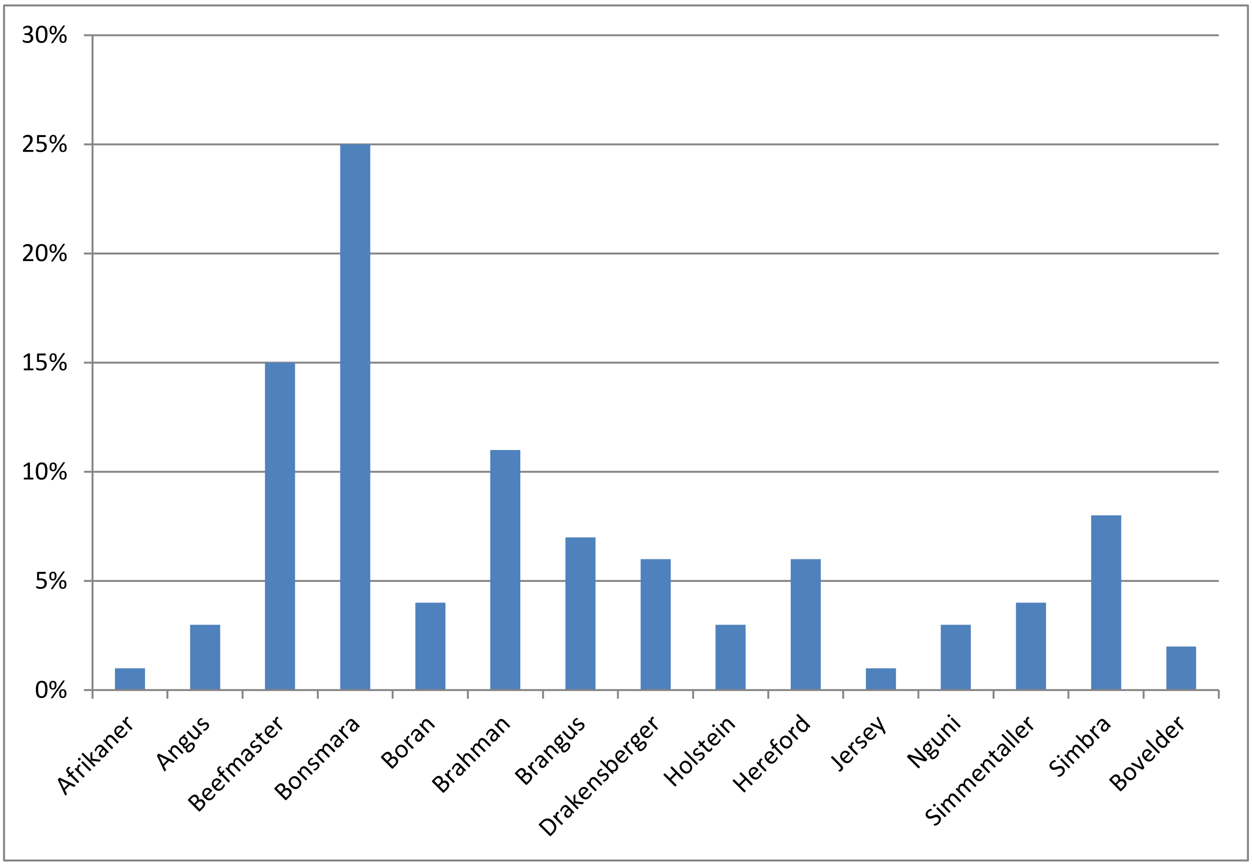

Figure: Cattle breeds of respondents surveyed in KwaZulu-Natal.

Table: Farmers personal information in KwaZulu-Natal province

Survey information	
Farmers average age (years)	50
Completion of school	65%
Further studies in agriculture	37%
Members of a farmer association	90%
Member of a producers association	95%
Experience as farmer (years)	23

Table: The number of cattle lost to predation in KwaZulu-Natal

Magistrate districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
eThekwini Metropolitan	0	298	0
Umzinyathi	130	44 085	0.29
Ugu	0	894	0
uMgundgundlovu	2	1 150	0.17
Uthukela	255	53 589	0.48
Amajuba	423	50 555	0.84
Zululand	111	37 948	0.29
Umkhanyakude	54	3 781	1.43
Uthungulu	2	273	0.73
Sisonke	178	38 818	0.46
Total	1 155	231 391	-

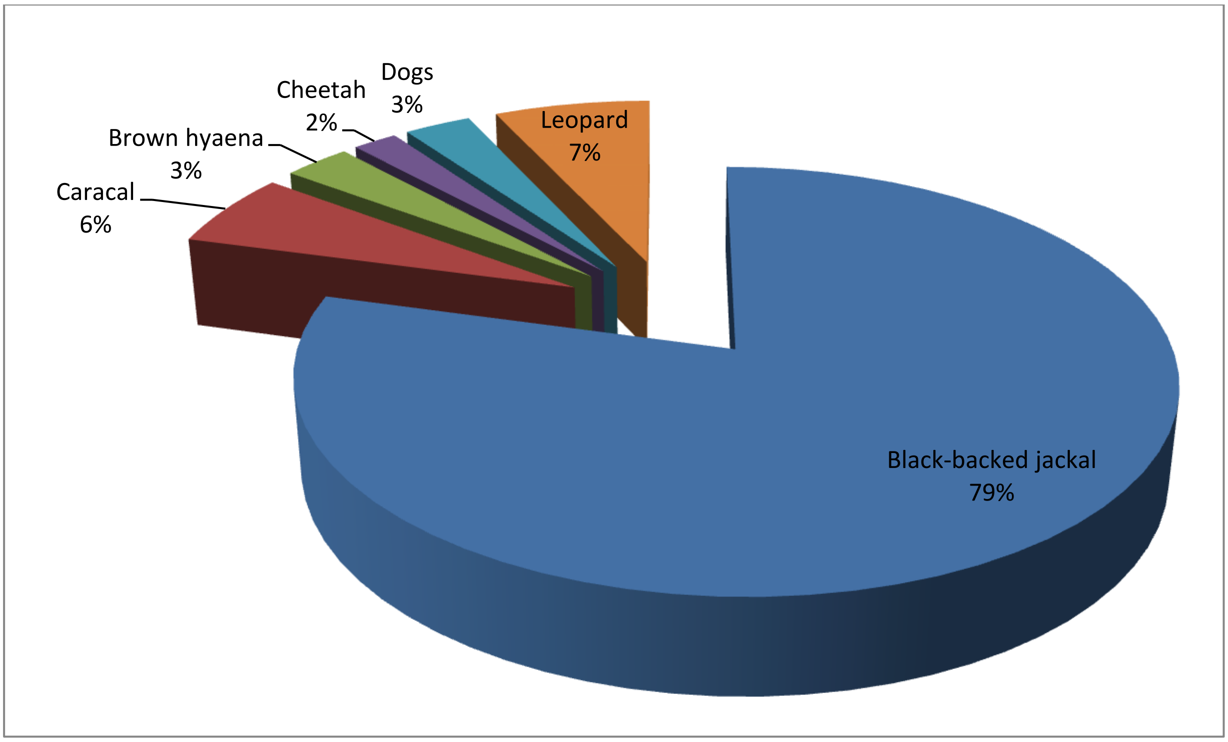

Figure: Predator species responsible for predation losses in KwaZulu-Natal.

Table: The direct cost of predation on cattle in KwaZulu-Natal

Magisterial district	Number of cattle in KwaZulu-Natal	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
eThekwini Metropolitan	739	0	0	10 400	0
Umzinyathi	61 079	0.29	180	10 400	1 872 000
Ugu	28 898	0	0	10 400	0
uMgundgundlovu	260 408	0.17	453	10 400	4 711 500
Uthukela	173 930	0.48	828	10 400	8 611 200
Amajuba	228 360	0.84	1911	10 400	19 874 400
Zululand	135 852	0.29	197	10 400	2 048 800
Umkhanyakude	29 201	1.43	417	10 400	4 336 800
Uthungulu	2 924	0.73	21	10 400	218 400
Sisonke	116 657	0.46	535	10 400	5 564 000
Total	1 038 048	-	4 542	-	47 237 100

Table: Costs of lethal predation management in KwaZulu-Natal

Magisterial district	Total lethal cost in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
eThekwini Metropolitan	0	298	0	739	0
Umzinyathi	100 200	44 085	2.27	61 079	138 825
Ugu	0	894	0	28 898	0
uMgundgundlovu	0	1 150	0	260 408	0
Uthukela	200 100	53 589	3.73	173 930	649 450
Amajuba	345 450	50 555	6.83	228 360	1 560 419
Zululand	238 000	37 948	6.27	135 852	852 028
Umkhanyakude	27 000	3 781	7.14	29 201	208 523
Uthungulu	0	273	0	2 924	0
Sisonke	46 000	38 818	1.19	116 657	138 241
Total	956 750	231 391	-	1 038 048	3 547 486

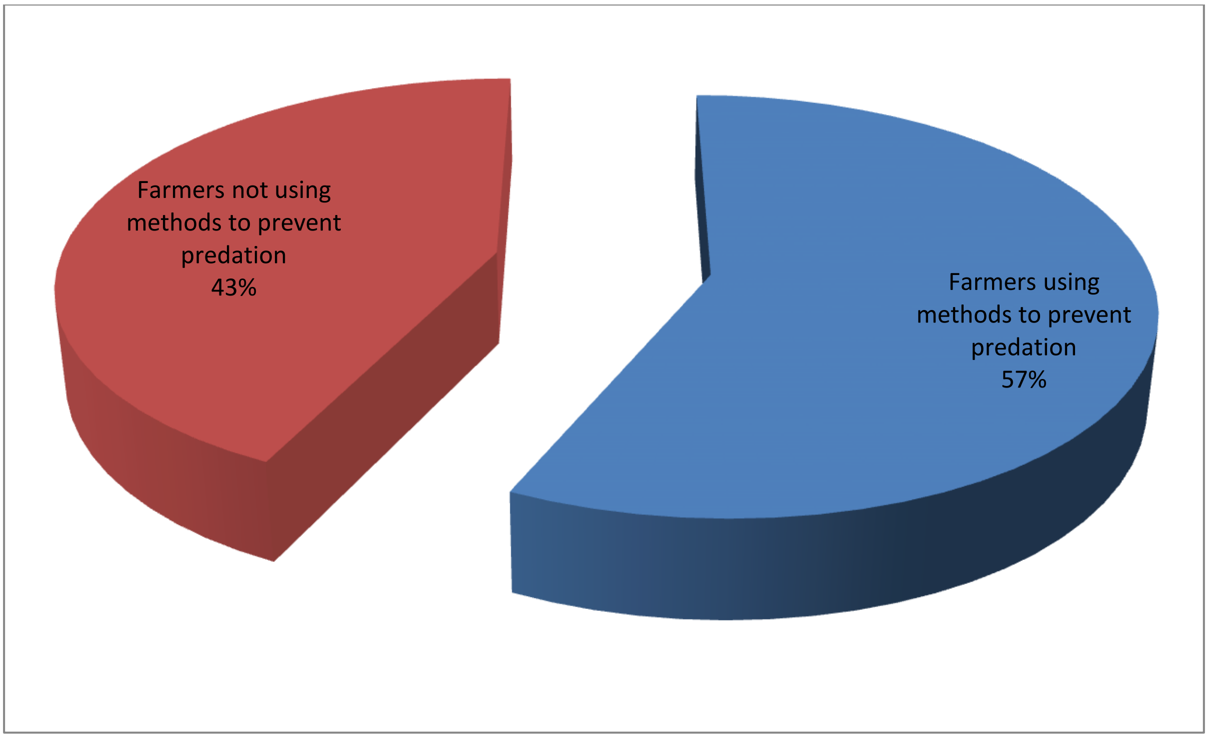

Figure: Percentage of farmers using predation management methods in KwaZulu-Natal.

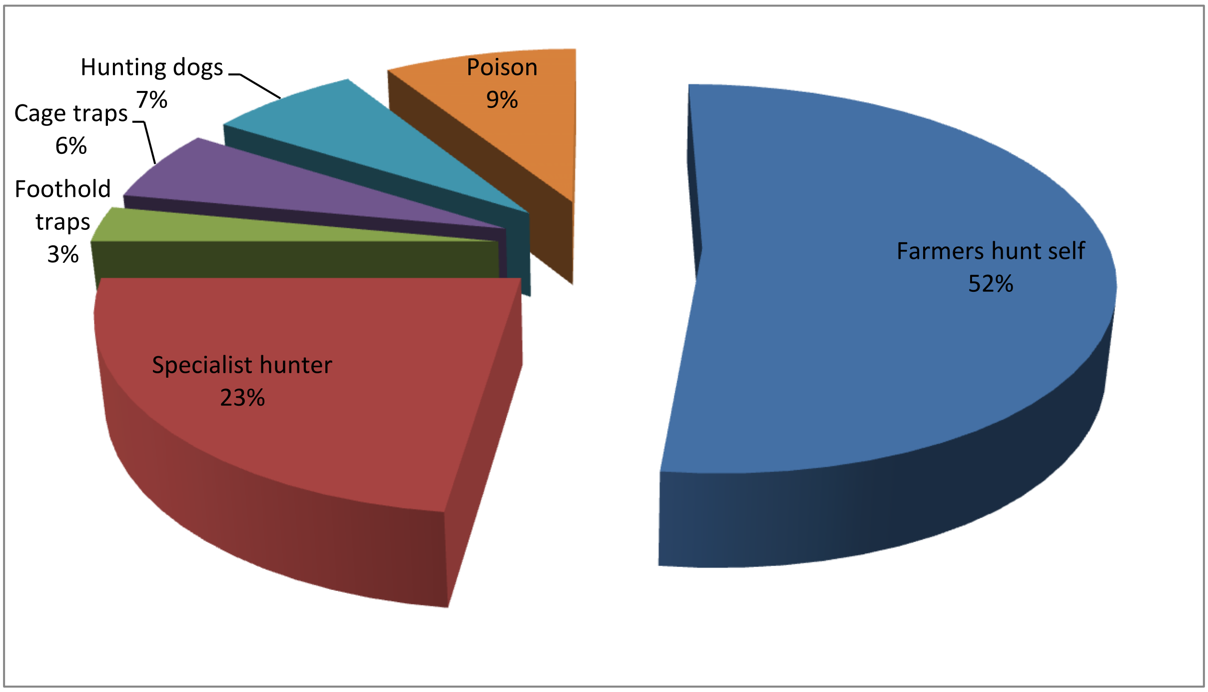

Figure: Percentage use of lethal prevention management methods in KwaZulu-Natal.

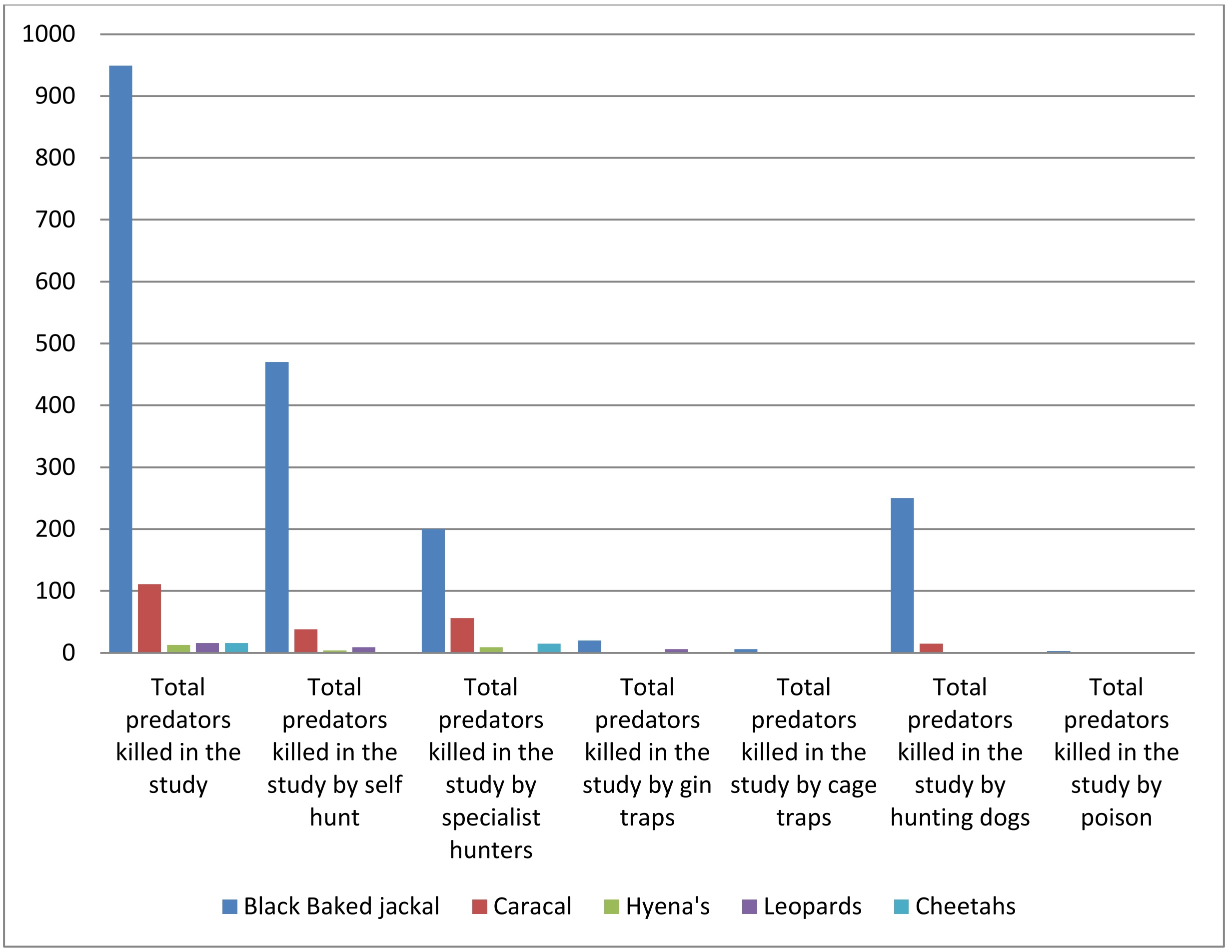

Figure: Number of predators killed with lethal methods in KwaZulu-Natal.

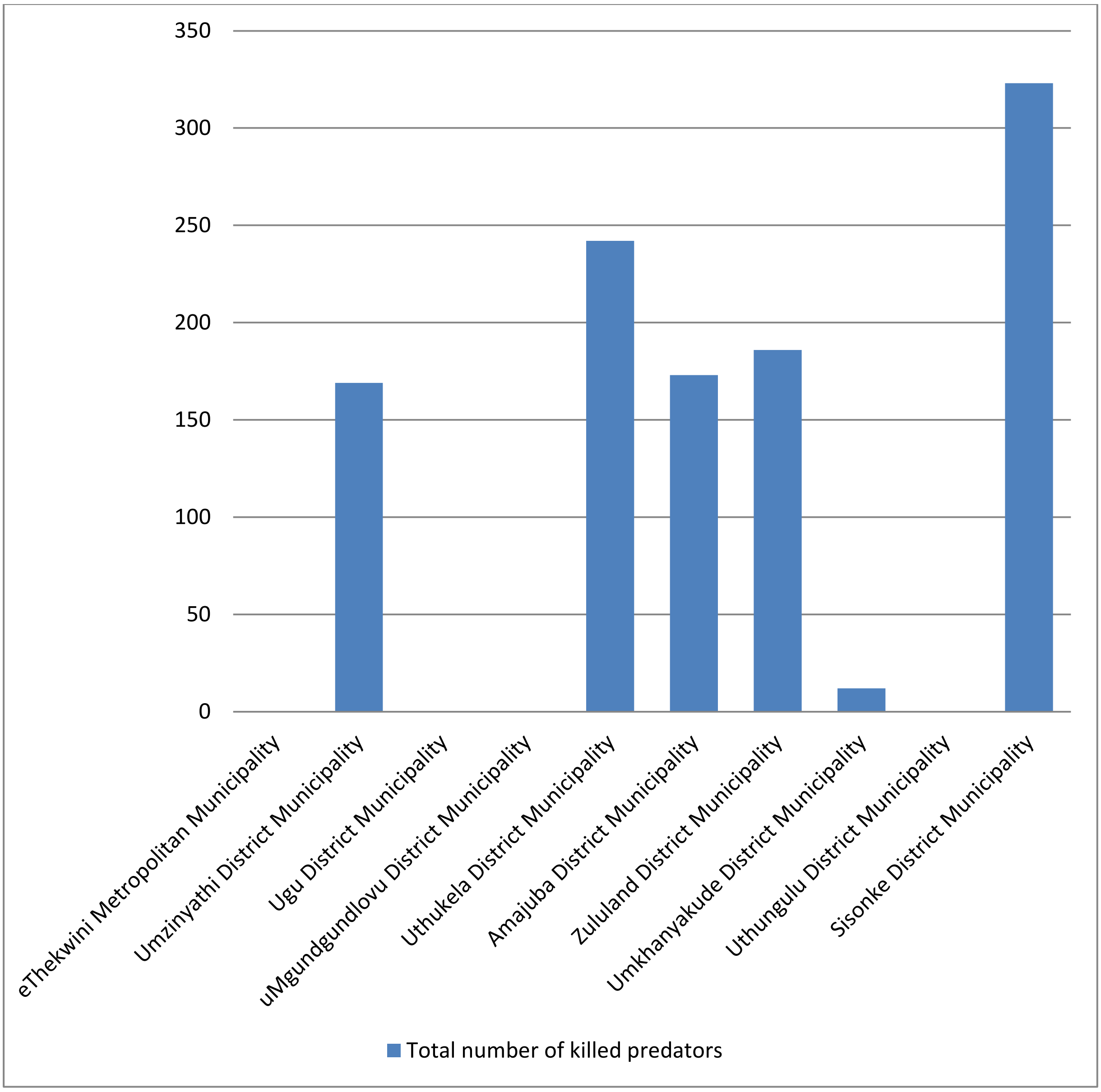

Figure: Total number of predators killed with lethal control methods in KwaZulu-Natal.

Table: The cost of non-lethal predation management in KwaZulu-Natal

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
eThekwini Metropolitan	38 400	298	128.86	739	95 227
Umzinyathi	1 834 881	44 085	41.62	61 079	2 542 196
Ugu	0	894	0	28 898	0
uMgundgundlovu	0	1 150	0	1 150	0
Uthukela	1 708 000	53 589	31.87	173 900	5 543 534
Amajuba	942 420	50 555	18.64	228 360	4 256 968
Zululand	285 000	37 948	7.51	135 852	1 020 286
Umkhanyakude	70 000	3 781	18.51	29 201	540 616
Uthungulu	0	273	0	2 924	0
Sisonke	414 100	38 818	10.67	116 657	1 244 466
Total	5 292 801	231 391	-	1 038 048	15 243 293

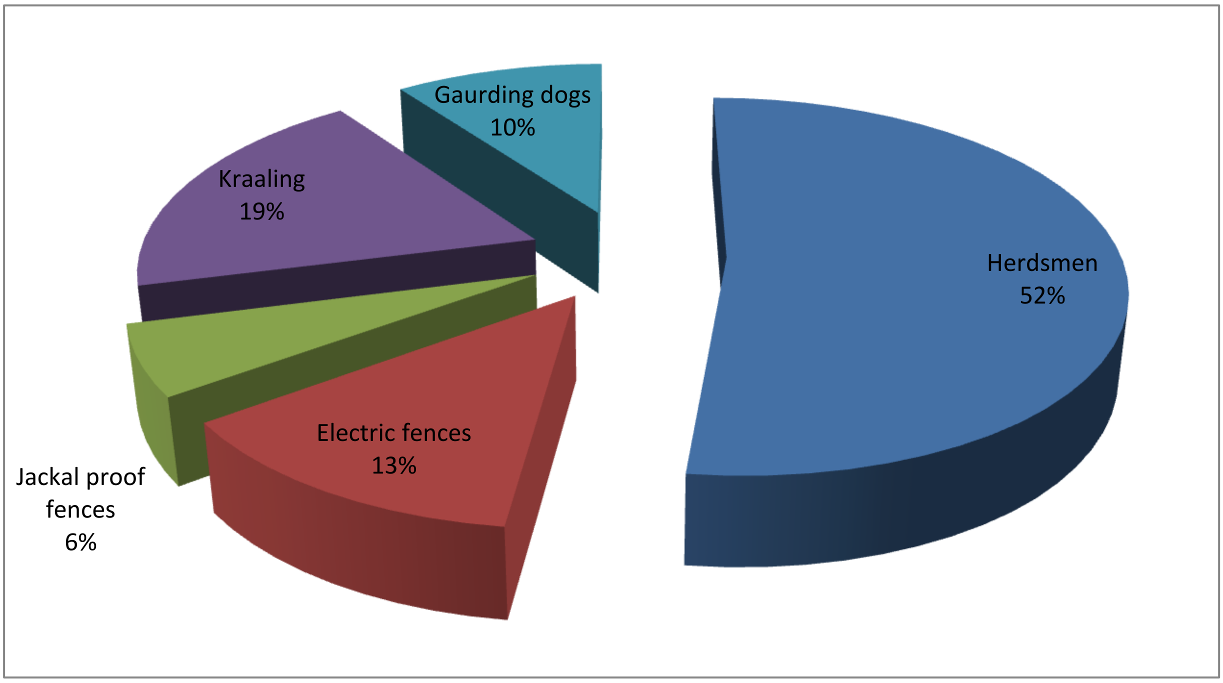

Figure: Percentage use of non-lethal methods to prevent predation in KwaZulu-Natal.

Table: The total direct and indirect cost of predation in KwaZulu-Natal

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost
eThekwini Metropolitan	0	95 227	0	95 227
Umzinyathi	138 825	2 542 196	1 872 000	4 553 021
Ugu	0	0	0	0
uMgundgundlovu	0	0	4 711 500	4 711 500
Uthukela	649 450	5 543 534	8 611 200	14 804 184
Amajuba	1 560 419	4 256 968	19 874 400	25 691 787
Zululand	852 028	1 020 286	2 048 800	3 921 114
Umkhanyakude	208 523	540 616	4 336 800	5 085 939
Uthungulu	0	0	218 400	218 400
Sisonke	138 241	1 244 466	5 564 000	6 946 707
Total	3 547 486	15 243 293	47 237 100	66 027 879

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.664
Bartlett's Test of Sphericity	Approx.Chi-Square	1071.446
	df	120
	Sig.	.000

Table: Results of the Communalities

	Initial	Extraction
Calving in January	1.000	0.821
Calving in February	1.000	0.819
Calving in April	1.000	0.796
Calving in May	1.000	0.879
Calving in June	1.000	0.676
Calving in August	1.000	0.554
Calving in November	1.000	0.789
Calving in December	1.000	0.764
Calving on grazing land	1.000	0.685
Calving on pastures	1.000	0.794
Pregnancy testing	1.000	0.525
Dehorn	1.000	0.655
Difficult birth	1.000	0.503
Gin traps	1.000	0.521
Hunting with dogs	1.000	0.541
Poison	1.000	0.676

Table: Percentage variance explained

	Rotation Sum of Squared Loadings		
Component	Eigen value	% of variance	Cumulative %
1	2.348	14.675	14.675
2	2.235	13.971	28.646
3	1.715	10.722	39.368
4	1.686	10.539	49.907
5	1.570	9.816	59.722
6	1.442	9.014	68.736

Table: Results from the Rotated Component Matrix

	Component					
	1	**2**	**3**	**4**	**5**	**6**
Calving in May	**0.889**	0.151	-0.065	-0.107	-0.126	0.127
Calving in April	**0.875**	0.046	-0.048	0.000	-0.158	-0.041
Calving in June	**0.660**	0.398	0.055	-0.229	-0.017	0.163
Calving in January	0.182	**0.858**	-0.048	-0.216	-0.054	0.016
Calving in February	0.343	**0.772**	-0.049	-0.131	-0.291	0.024
Calving in December	-0.017	**0.753**	-0.037	0.056	0.438	0.009
Poison	0.039	-0.033	**0.810**	-0.087	0.006	-0.093
Hunting with dogs	-0.014	-0.073	**0.714**	0.073	-0.142	0.016
Gin traps	-0.080	0.025	**0.711**	0.002	0.089	0.017
Dehorn	0.039	0.019	0.011	**0.803**	0.063	0.065
Difficult birth	-0.053	-0.076	-0.046	**0.701**	-0.024	-0.021
Pregnancy testing	-0.265	-0.224	0.047	**0.629**	-0.045	-0.072
Calving in November	0.112	0.132	0.039	0.048	**0.867**	-0.059

Calving in August	0.274	0.261	0.125	0.087	**-0.600**	0.168
Calving on pastures	0.133	0.066	0.011	-0.002	0.079	**0.875**
Calving on grazing land	-0.011	0.024	0.075	0.010	0.312	**-0.762**

Table: Results of Logit regression to identify mitigating factors that affect the occurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of Farm	0.274	0.220
Farmer's age	0.043	0.834
Completion of school	0.141	0.504
Further studies in agriculture	0.139	0.338
Member of a farmer's association	0.099	0.572
Member of a producer's association	0.004	0.984
Experience as a farmer	0.312	0.151
Managerial factors		
Size of breeding herd	0.259	0.245
Calving in January	-0.113	0.389
Calving in February	-0.150	0.354
Calving in March	0.005	0.979
Calving in April	0.082	0.708
Calving in May	0.038	0.856
Calving in June	0.039	0.807
Calving in July	0.040	0.837
Calving in August	-0.041	0.789

Calving in September	-0.122	0.469
Calving in October	-0.143	0.347
Calving in November	0.063	0.687
Calving in December	-0.009	0.948
Calving on grazing land	0.008	0.961
Calving on pastures	0.044	0.792
Calving on crop residues	0.038	0.845
Calving in the kraal	0.090	0.593
Times counted per month	-0.051	0.815
Times worked with livestock per month	-0.077	0.672
Age at first conception	0.424	0.207
Pregnancy testing	-0.083	0.369
Dehorn	0.101	0.534
Remove of dead animals	0.144	0.304
Record of difficult births	0.055	0.766
Sheep	0.077	0.684
Non-lethal methods		
Herdsmen	0.045	0.721
Jackals proof	0.015	0.905
Electric fences	0.060	0.709
Lights	-0.233	0.375
Kraaling	0.037	0.858
Guarding animals	0.010	0.934
Lethal methods		
Farmer himself hunts	0.699	0.024***
Specialist hunters	0.593	0.022***
Gin traps	-0.033	0.829
Cage traps	0.089	0.595
Hunting with dogs	0.143	0.515
Poison	0.222	0.299

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Results of Truncated regression to identify mitigating factors that affect the level of predation.

	Truncated	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	0.002	0.176
Farmer's age	0.003	0.038***
Completion of school	0.003	0.012***
Further studies in agriculture	0.002	0.015***
Member of a farmer's association	0.003	0.010****
Member of a producer's association	0.001	0.484
Experience as a farmer	0.005	0.003****
Managerial factors		
Number of breeding animals	0.001	0.635
Calving in January	-0.001	0.389
Calving in February	-0.001	0.215
Calving in March	0.001	0.268
Calving in April	0.002	0.157
Calving in May	0.001	0.488
Calving in June	0.001	0.068**
Calving in July	0.001	0.615
Calving in August	-0.001	0.188
Calving in September	-0.001	0.075**
Calving in October	-0.003	0.001****
Calving in November	0.001	0.617
Calving in December	0000	0.761
Calving on grazing land	0.002	0.006****
Calving on pastures	-0.001	0.470
Calving on crop residues	-0.001	0.542
Calving in the kraal	0.001	0.212
Times counted per month	0.000	0.671
Times worked with livestock per month	-0.002	0.016

Age at first conception	0.006	0.001****
Pregnancy testing	-0.001	0.008****
Dehorn	0.002	0.037***
Remove of dead animals	0.002	0.007****
Recording of difficult births	0.000	0.879
Sheep	0.001	0.315
Non-lethal methods		
Herdsmen	-0.001	0.403
Jackals proof	-0.001	0.340
Electric fences	-0.002	0.152
Lights	-0.002	0.137*
Kraaling	0.002	0.039***
Guarding animals	0.000	0.686
Lethal methods		
Farmer himself hunts	0.005	0.001****
Specialist hunters	0.006	0.000****
Gin traps	-0.002	0.020***
Cage traps	0.003	0.001****
Hunting with dogs	0.001	0.703
Poison	0.000	0.796

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Logit regression

Null Hypothesis:	**Probability (Logit)**
Farmer himself hunts does not Granger Cause predation	0.139*
Specialist hunters does not Granger Cause predation	0.130*

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Truncated regression

Null Hypothesis:	Probability (Truncated)
Age of the farmer does not Granger Cause predation	0.216
Completion of school does not Granger Cause predation	0.383
Further studies in agriculture does not Granger Cause predation	0.293
Member of a farmer's association does not Granger Cause predation	0.105*
Experience as a farmer does not Granger Cause predation	0.079**
Calving in June does not Granger Cause predation	0.501
Calving in September does not Granger Cause predation	0.118*
Calving in October does not Granger Cause predation	0.954
Calving on grazing land does not Granger Cause predation	0.865
Times worked with livestock per month does not Granger Cause predation	0.601
Age at first conception does not Granger Cause predation	0.216
Pregnancy testing does not Granger Cause predation	0.841
Dehorn does not Granger Cause predation	0.612
Remove of dead animals does not Granger Cause predation	0.034***
Lights does not Granger Cause predation	0.999
Kraaling does not Granger Cause predation	0.940
Farmer himself hunts does not Granger Cause predation	0.459
Specialist hunters does not Granger Cause predation	0.583
Gin traps does not Granger Cause predation	0.976
Cage traps does not Granger Cause predation	0.864

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Appendix E: Limpopo

The primary information obtained in the survey from **80 responding farmers** in the Limpopo province.

Table: Number of farmers surveyed, land utilisation and cattle numbers in Limpopo

	Surveyed	Limpopo	Percentage
Farmers	80	2 644	3.0
Head of cattle	30 489	411 080	7.4
Grazing land (ha)	204 308	8 847 848	2.3

Source: NDA, 2012

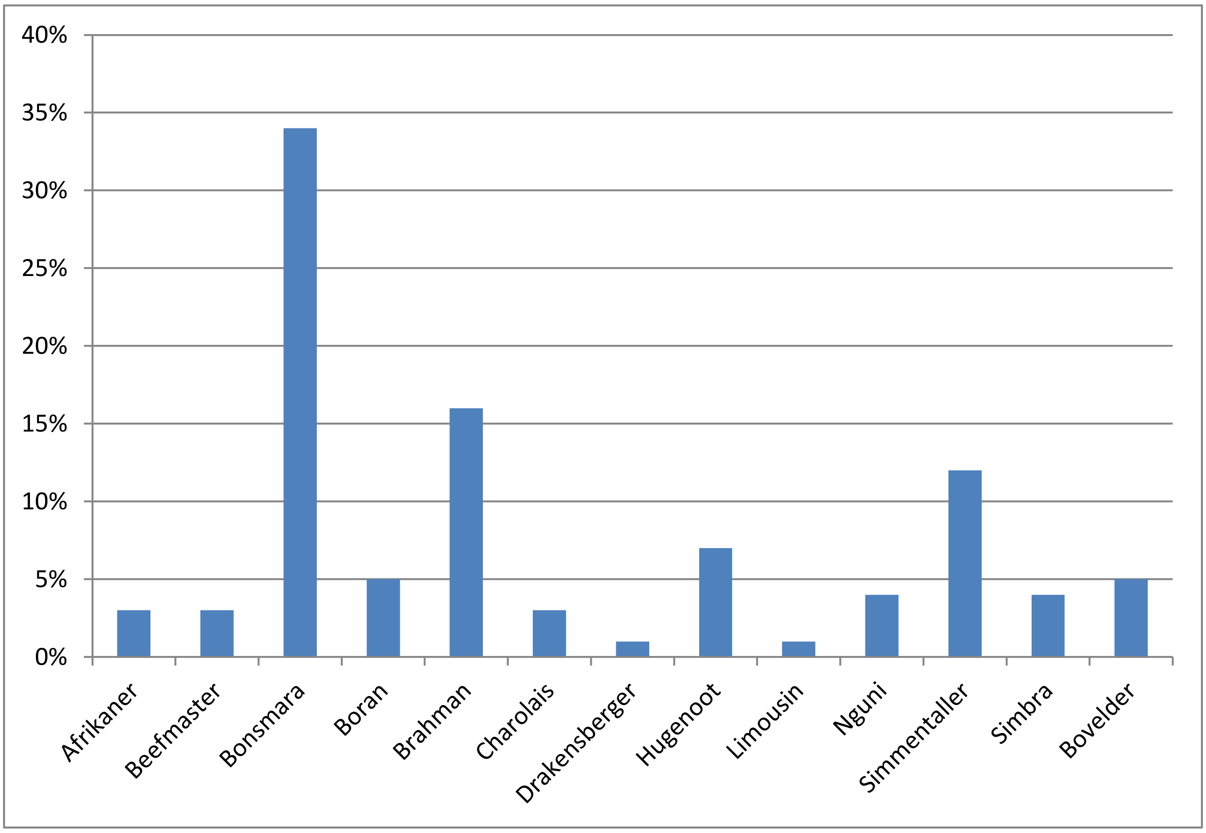

Figure: Cattle breeds of respondents surveyed in Limpopo.

Table: Farmers personal information for the Limpopo province

Survey information	
Farmers average age (years)	53
Completion of school	56%
Further studies in agriculture	19%
Members of a farmer association	82%
Member of a producers association	88%
Experience as farmer (years)	25

Table: The number of cattle lost to predation in Limpopo

Magisterial districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
Mopani	4	748	0.53
Capricorn	0	2124	0
Vhembe	0	133	0
Waterberg	206	21 142	0.97
Greater Sekhukhune	52	6 342	0.82
Total	262	30 489	-

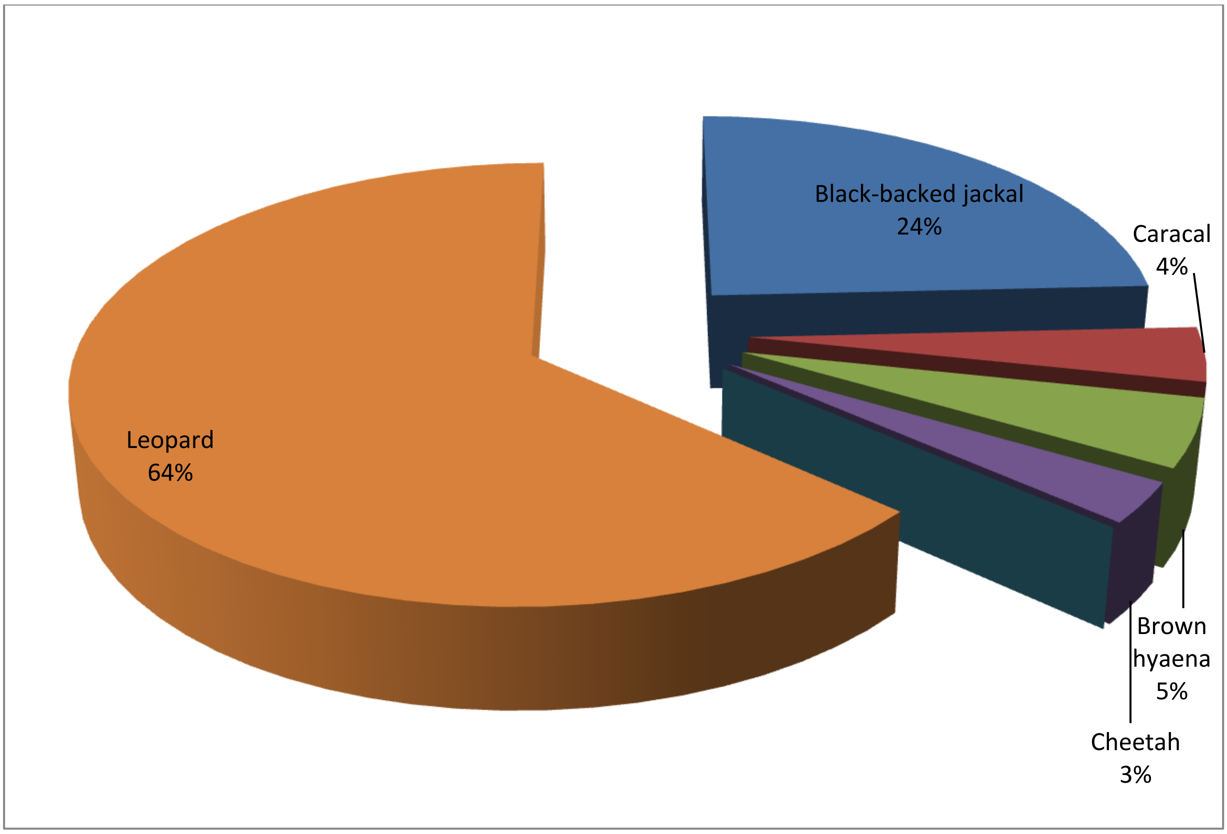

Figure: Predator species responsible for predation losses in Limpopo.

Table: The direct cost of predation on cattle in Limpopo

Magisterial district	Number of cattle in Limpopo	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
Mopani	5 070	0.53	27	10 400	280 800
Capricorn	4 354	0	0	10 400	0
Vhembe	16 087	0	0	10 400	0
Waterberg	314 982	0.97	3 069	10 400	31 917 600
Greater Sekhukhune	70 587	0.82	579	10 400	6 021 600
Total	411 080	-	3 675	-	38 220 000

Table: Cost of lethal predation management in Limpopo

Magistrate district	Total lethal cost in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
Mopani	3 000	748	4.01	5 070	20 334
Capricorn	20 000	2 124	9.42	4 354	40 998
Vhembe	0	133	0	16 087	0
Waterberg	210 200	21 142	9.94	314 982	3 131 644
Greater Sekhukhune	39 500	6 342	6.23	70 587	439 638
Total	272 700	30 489	-	411 080	3 632 614

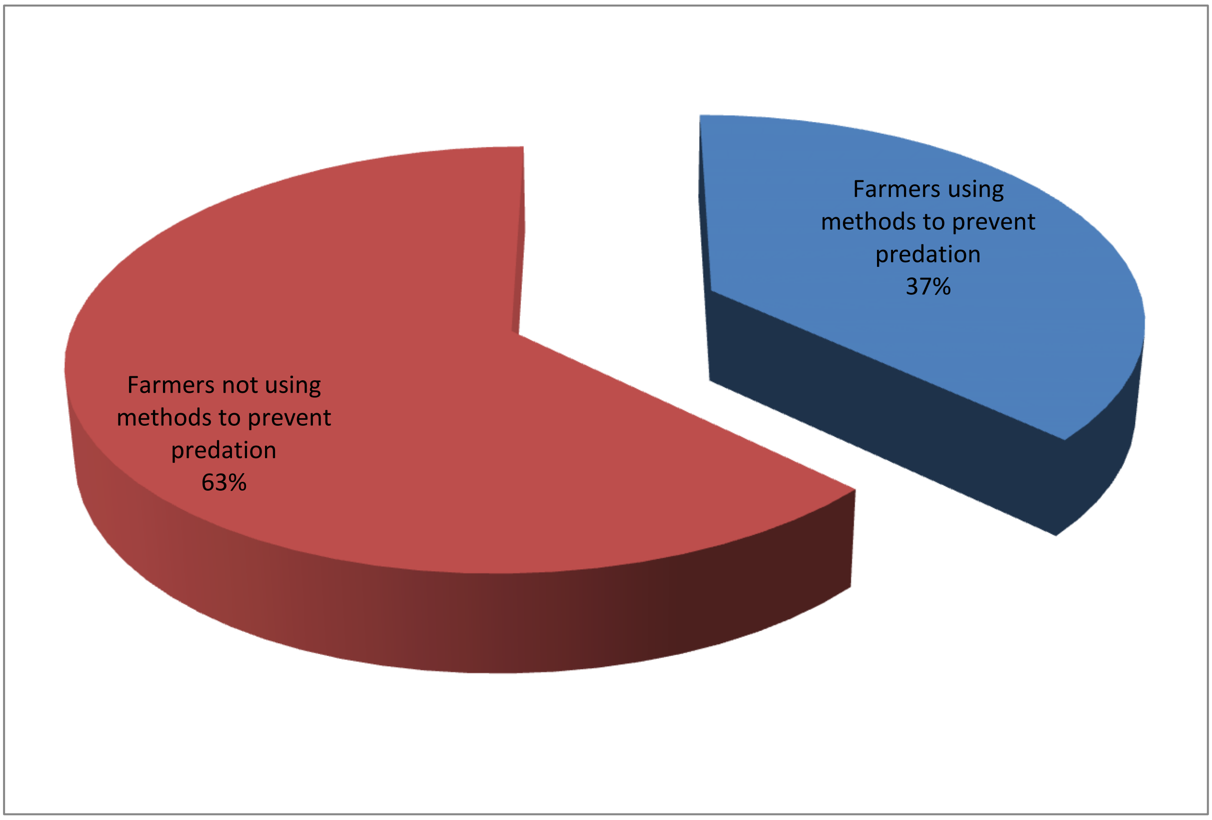

Figure: Percentage of farmers using predation management methods in Limpopo.

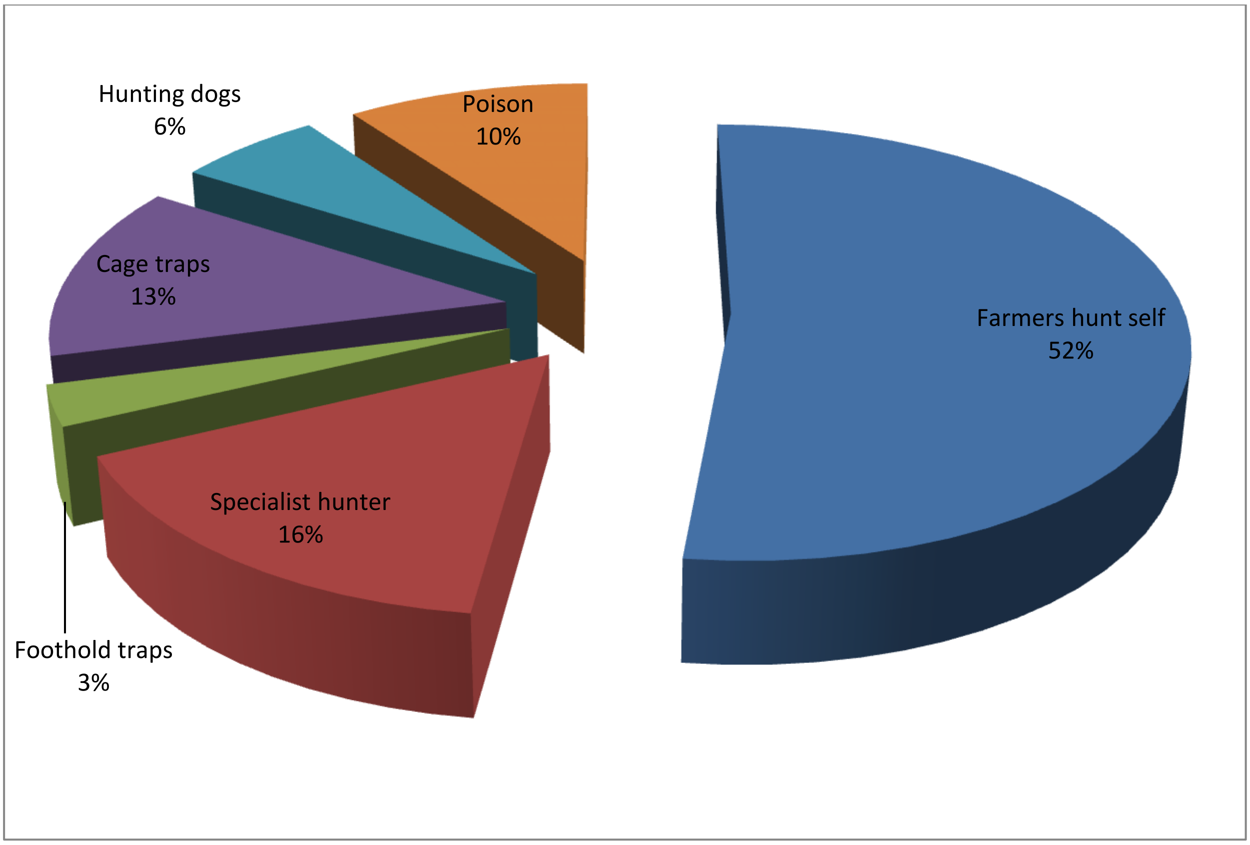

Figure: Percentage use of lethal prevention management methods in Limpopo.

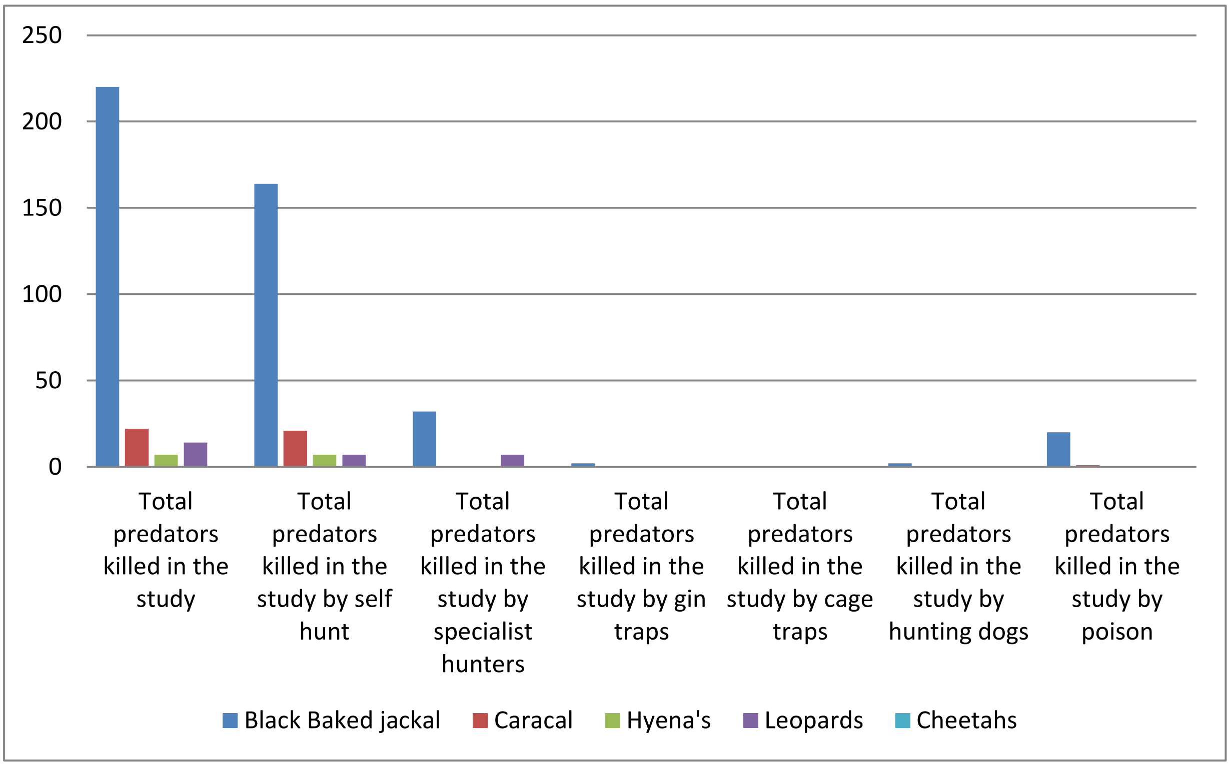

Figure: Number of predators killed with lethal methods in Limpopo.

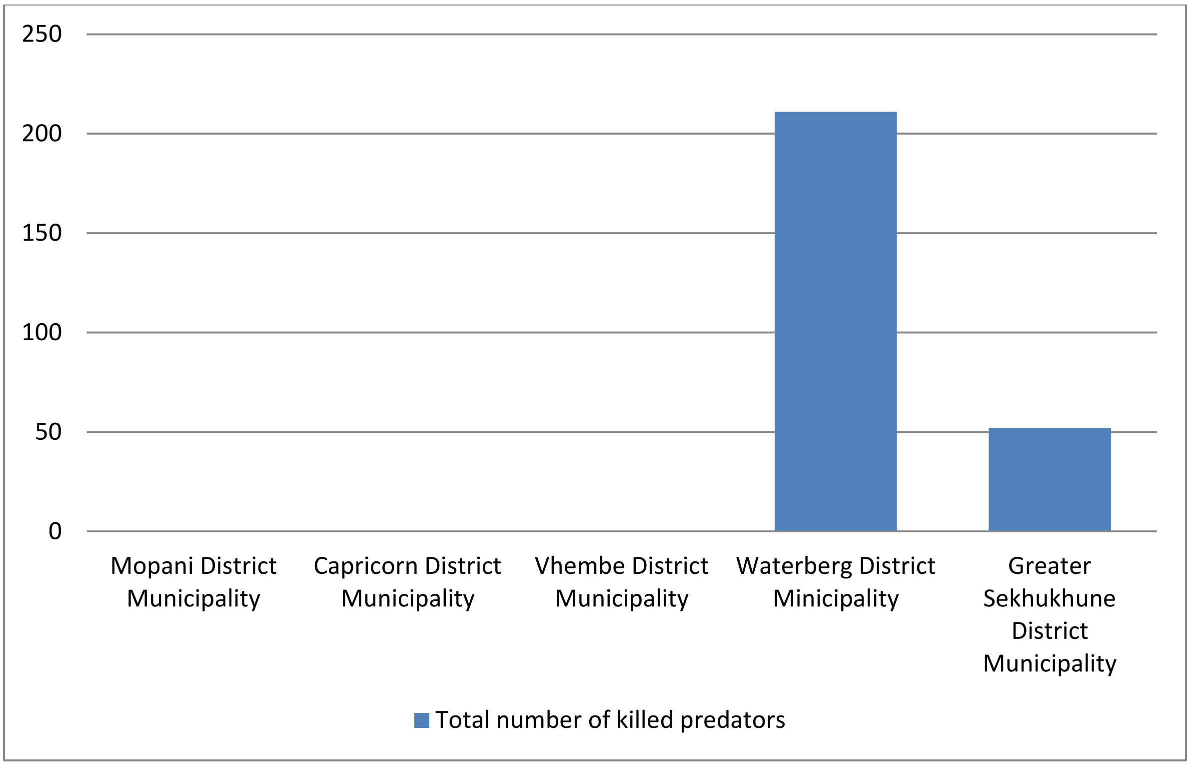

Figure: Total number of predators killed with lethal methods in Limpopo.

Table: The cost of non-lethal predation management in Limpopo

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
Mopani	0	748	0	5 070	0
Capricorn	0	2 124	0	4 354	0
Vhembe	0	133	0	16 087	0
Waterberg	311 000	21 142	14.71	314 982	4 633 403
Greater Sekhukhune	0	6 342	0	70 587	0
Total	311 000	30 489	-	411 080	4 633 403

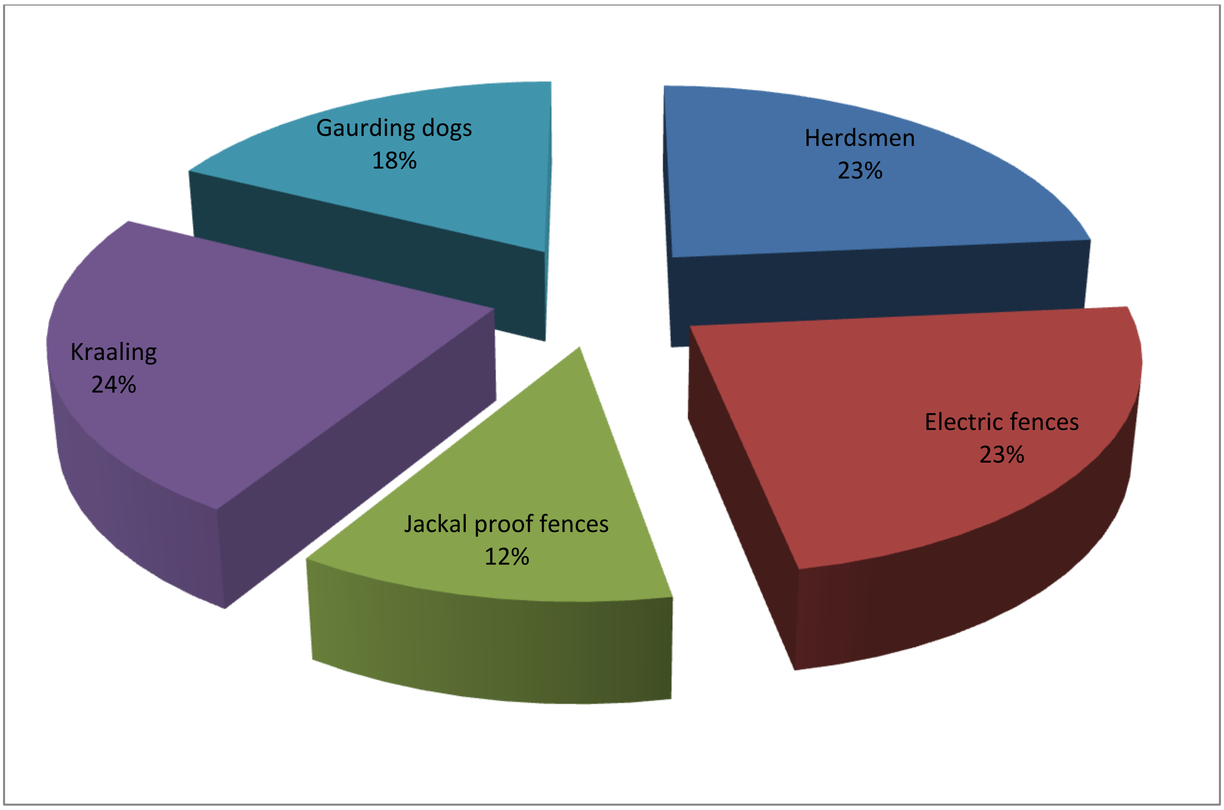

Figure: Percentage use of non-lethal management methods to prevent predation in Limpopo.

Table: The total direct and indirect cost of predation in Limpopo

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost
Mopani	20 334	0	280 800	301 134
Capricorn	40 998	0	0	40 998
Vhembe	0	0	0	0
Waterberg	3 131 644	4 633 403	31 917 600	39 682 647
Greater Sekhukhune	439 638	0	6 021 600	6 461 238
Total	3 632 614	4 633 403	38 220 000	46 486 017

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.715
Bartlett's Test of Sphericity	Approx.Chi-Square	703.563
	df	153
	Sig.	0.000

Table: Results of the Communalities

	Initial	Extraction
Size of breeding herd	1.000	0.624
Calving in January	1.000	0.815
Calving in February	1.000	0.759
Calving in March	1.000	0.861
Calving in April	1.000	0.852
Calving in May	1.000	0.857
Calving in June	1.000	0.835
Calving in July	1.000	0.755
Calving in October	1.000	0.843
Calving in December	1.000	0.580
Calving op pastures	1.000	0.715
Times counted per month	1.000	0.600
Age at first conception	1.000	0.606
Dehorn	1.000	0.698
Poison	1.000	0.597
Specialist hunters	1.000	0.635
Farmer himself hunts	1.000	0.717
Calving on grazing land	1.000	0.588

Table: Percentage variance explained

Component	Rotation Sum of Squared Loadings		
	Eigen value	% of variance	Cumulative %
1	5.127	28.486	28.486
2	1.990	11.054	39.539
3	1.877	10.426	49.966
4	1.384	7.689	57.655
5	1.344	7.464	65.199
6	1.214	6.746	71.866

Table: Results from the Rotated Component Matrix

	Component					
	1	**2**	**3**	**4**	**5**	**6**
Calving in March	**0.849**	0.281	-0.184	-0.055	-0.020	0.156
Calving in June	**0.835**	0.201	0.012	0.242	-0.171	-0.101
Calving in May	**0.834**	0.382	0.049	0.003	-0.050	-0.103
Calving in July	**0.828**	0.075	0.032	0.202	-0.136	-0.056
Calving in April	**0.816**	0.387	-0.138	-0.119	-0.012	0.065
Calving in February	**0.768**	-0.248	-0.084	-0.296	0.078	0.075
Calving in January	**0.712**	-0.454	-0.077	-0.261	0.107	0.123
Calving in December	**0.605**	-0.055	0.107	0.150	0.387	0.163
Calving in	0.186	**0.867**	0.000	0.130	0.133	0.145

October						
Age at first conception	-0.192	**-0.698**	-0.242	0.060	0.105	-0.091
Calving on pastures	0.102	0.095	**0.769**	-0.072	0.178	-0.260
Farmer himself hunts	-0.046	0.088	**0.728**	-0.026	-0.039	0.419
Size of breeding herd	-0.246	0.065	**0.704**	0.167	-0.181	0.051
Specialist hunters	0.081	0.014	0.253	**0.707**	0.243	-0.066
Calving on grazing land	-0.018	0.044	-0.224	**0.639**	-0.307	0.181
Dehorn	-0.063	0.016	-0.047	-0.018	**0.828**	-0.078
Poison	0.186	0.102	0.061	-0.094	-0.312	**0.665**
Times counted per month	-0.095	0.157	-0.016	0.342	0.309	**0.595**

Table: Results of Logit regression to identify mitigating factors that affect theoccurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	-0.028	0.782
Farmer's age	0.001	0.995
Completion of school	0.015	0.905
Further studies in agriculture	-0.042	0.709
Member of a farmer's association	-0.164	0.482
Member of a producer's association	-0.124	0.382

Experience as a farmer	-0.003	0.978
Managerial factors		
Size of breeding herd	0.204	0.176
Calving in January	0.018	0.680
Calving in February	-0.049	0.617
Calving in March	-0.045	0.369
Calving in April	-0.056	0.137*
Calving in May	-0.032	0.317
Calving in June	0.040	0.260
Calving in July	03098	0.139*
Calving in August	0.123	0.245
Calving in September	0.057	0.697
Calving in October	-0.021	0.727
Calving in November	0.092	0.488
Calving in December	0.049	0.693
Calving on grazing land	0.198	0.211
Calving on pastures	0.199	0.201
Calving on crop residues	0.015	0.825
Calving in the kraal	-0.232	0.130*
Times counted per month	0.115	0.110*
Times worked with livestock per month	-0.059	0.433
Age at first conception	0.086	0.559
Pregnancy testing	0.205	0.169
Dehorn	-0.096	0.332
Removal of dead animals	0.172	0.104*
Recording of difficult births	0.136	0.154
Sheep	-0.108	0.395
Non-lethal methods		
Herdsmen	-0.129	0.558
Jackals proof	0.137	0.154
Electric fences	-0.125	0.336
Lights	-0.014	0.884
Kraaling	0.065	0.438

Guarding animals	-0.061	0.237
Lethal methods		
Farmer himself hunts	-0.029	0.844
Specialist hunters	0.180	0.103*
Gin traps	0.175	0.097**
Cage traps	0.109	0.150*
Hunting with dogs	0.171	0.124*
Poison	-0.127	0.273

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Results of Truncated regression to identify mitigating factors that affect the level of predation

	Truncated	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	-0.028	0.000****
Farmer's age	-0.008	0.001****
Completion of school	0.004	0.014***
Further studies in agriculture	-0.016	0.000****
Member of a farmer's association	-0.004	0.179
Member of a producer's association	0.001	0.633
Experience as a farmer	-0.014	0.000****
Managerial factors		
Size of breeding herd	-0.023	0.000****
Calving in January	0.001	0.657
Calving in February	0.001	0.341
Calving in March	0.002	0.014***
Calving in April	0.001	0.124*
Calving in May	0.000	0.838
Calving in June	0.001	0.207
Calving in July	0.001	0.361
Calving in August	-0.002	0.330
Calving in September	-0.006	0.019***

Calving in October	-0.002	0.248
Calving in November	-0.006	0.017***
Calving in December	-0.006	0.023***
Calving on grazing land	0.000	0.940
Calving on pastures	-0.002	0.491
Calving on crop residues	0.024	0.000****
Calving in the kraal	0.002	0.465
Times counted per month	0.011	0.000****
Times worked with livestock per month	0.002	0.432
Age at first conception	0.007	0.000****
Pregnancy testing	0.000	0.959
Dehorn	0.020	0.000****
Removal of dead animals	0.011	0.000****
Recording of difficult births	0.004	0.138*
Sheep	0.011	0.000****
Non-lethal methods		
Herdsmen	0.001	0.791
Jackals proof	0.001	0.653
Electric fences	0.030	0.000****
Lights	-0.001	0.826
Kraaling	-0.008	0.020***
Guarding animals	0.001	0.641
Lethal methods		
Farmer himself hunts	-0.001	0.000****
Specialist hunters	-0.006	0.047***
Gin traps	-0.003	0.114*
Cage traps	0.002	0.514
Hunting with dogs	-0.007	0.001****
Poison	0.025	0.000****

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Logit regression

Null Hypothesis:	Probability (Logit)
Calving in April does not Granger Cause predation	0.243
Calving in July does not Granger Cause predation	0.780
Calf in the kraal does not Granger Cause predation	0.853
Times counted per month does not Granger Cause predation	0.746
Removal of dead animals does not Granger Cause predation	0.123*
Specialist hunters does not Granger Cause predation	0.664
Gin traps does not Granger Cause predation	0.522
Cage traps does not Granger Cause predation	0.105*
Hunting with dogs does not Granger Cause predation	0.261

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Truncated regression

Null Hypothesis:	Probability (Truncated)
Size of farm does not Granger Cause predation	0.923
Farmer's age does not Granger Cause predation	0.913
Completion of school does not Granger Cause predation	0.472
Further studies in agriculture does not Granger Cause predation	0.902
Experience as a farmer does not Granger Cause predation	0.827
Size of breeding herd does not Granger Cause predation	0.308
Calving in March does not Granger Cause predation	0.109*
Calving in April does not Granger Cause predation	0.051**
Calving in September does not Granger Cause predation	0.117*
Calving in November does not Granger Cause predation	0.521
Calving in December does not Granger Cause predation	0.066**

Calving on crop residues does not Granger Cause predation	0.656
Times counted per month does not Granger Cause predation	0.460
Age at first conception does not Granger Cause predation	0.492
Dehorn does not Granger Cause predation	0.801
Removal of dead animals does not Granger Cause predation	0.004****
Recording of difficult births does not Granger Cause predation	0.614
Sheep does not Granger Cause predation	0.046***
Electric fences does not Granger Cause predation	0.519
Kraaling does not Granger Cause predation	0.937
Farmer himself hunts does not Granger Cause predation	0.722
Specialist hunters does not Granger Cause predation	0.980
Gin traps does not Granger Cause predation	0.789
Hunting with dogs does not Granger Cause predation	0.614
Poison does not Granger Cause predation	0.791

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Appendix F: Mpumalanga

the primary information obtained in the survey from **176 responding farmers** in the Mpumalanga province.

Table: Number of farmers surveyed, land utilisation and cattle numbers in Mpumalangaf

	Surveyed	Mpumalanga	Percentage
Farmers	176	2 336	7.5
Head of cattle	179 078	901 801	19.9
Grazing land (ha)	393 833	3 243 931	12.1

Source: NDA, 2012

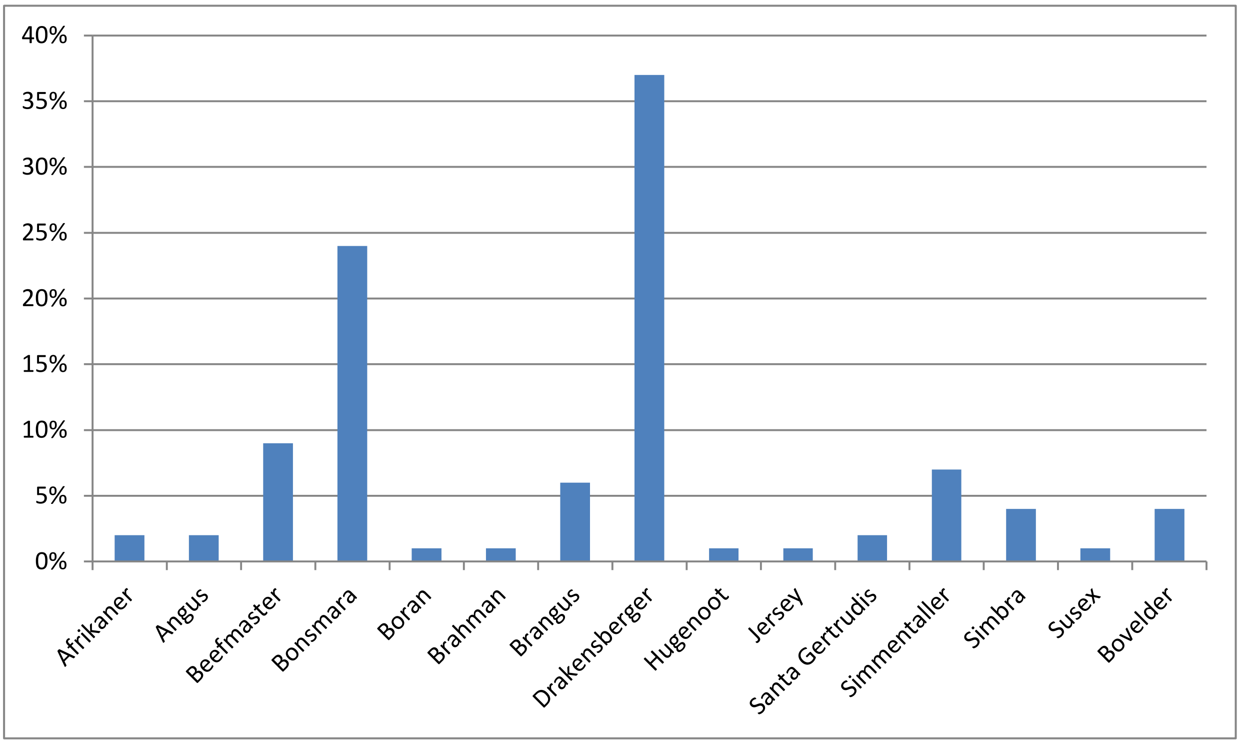

Figure: Cattle breeds of respondents surveyed in Mpumalanga.

Table: Farmers personal information for Mpumalanga province

Survey information	
Farmers average age (years)	50
Completion of school	60%
Further studies in agriculture	38%
Members of a farmer association	74%
Member of a producers association	71%
Experience as farmer (years)	26

Table: The number of cattle lost to predation in different magisterial district in Mpumalanga

Magisterial districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
Gert Sibande	229	139 696	0.16
Nkangala	153	32 392	0.47
Ehlanzeni	82	6 990	1.17
Total	464	179 078	-

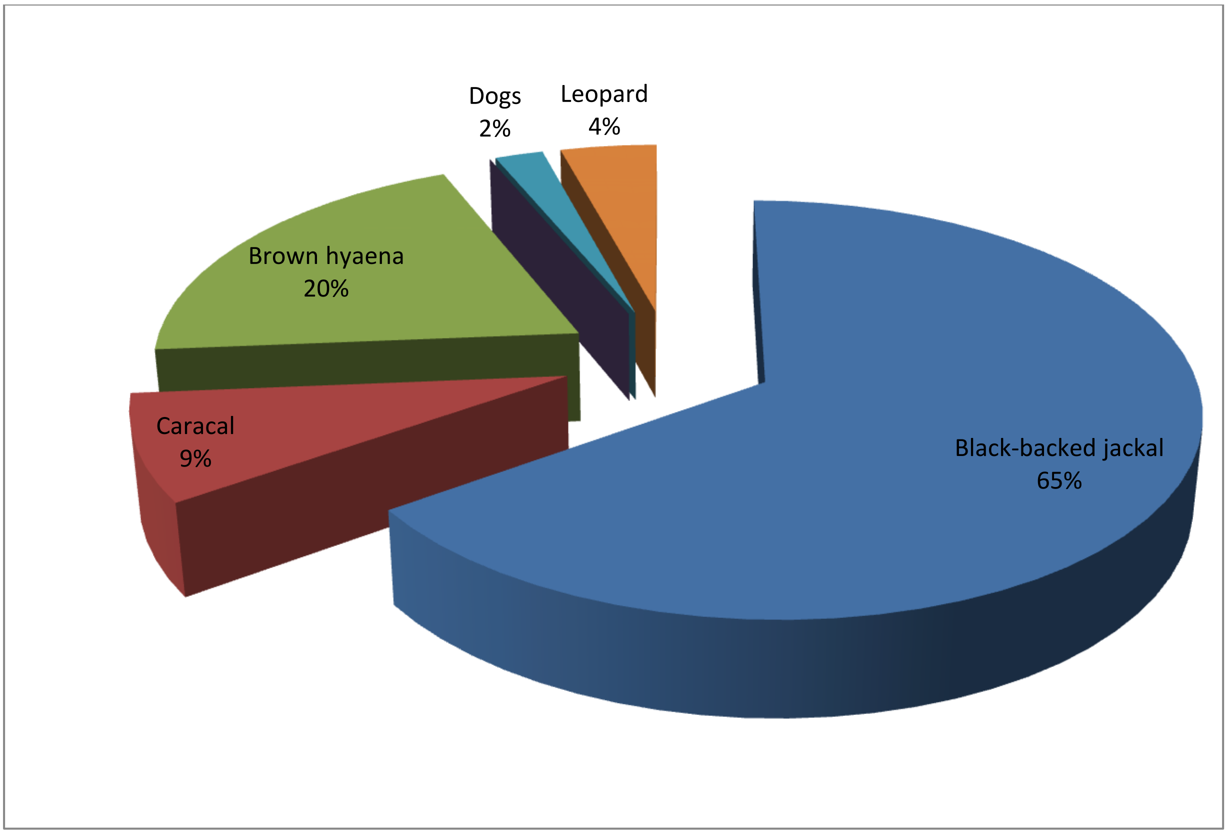

Figure: Predator species responsible for losses in Mpumalanga.

Table: The direct cost of predation on cattle in Mpumalanga

Magisterial district	Number of cattle in Mpumalanga	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
Gert Sibande	602 865	0.16	988	10 400	10 275 200
Nkangala	227 814	0.47	1 076	10 400	11 190 400
Ehlanzeni	71 122	1.17	834	10 400	8 673 600
Total	901 801	-	2 898	-	30 139 200

Table: Costs of lethal predation management in Mpumalanga

Magistrate district	Total cost lethal in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
Gert Sibande	674 900	139 696	4.83	602 865	2 912 564
Nkangala	113 500	32 392	3.50	227 814	798 249
Ehlanzeni	12 000	6 990	1.72	71 122	122 098
Total	800 400	179 078	-	901 801	3 832 911

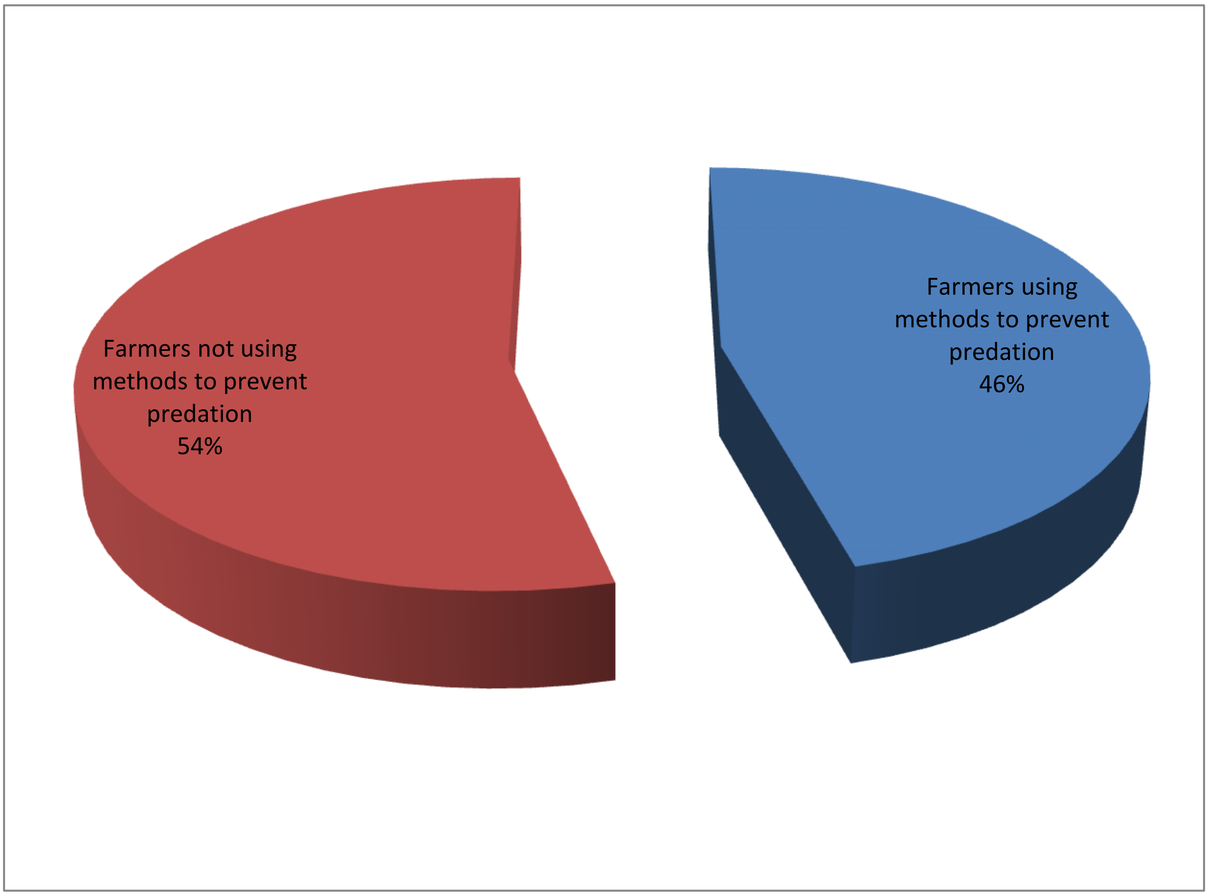

Figure: Percentage of farmers using predation management methods in Mpumalanga.

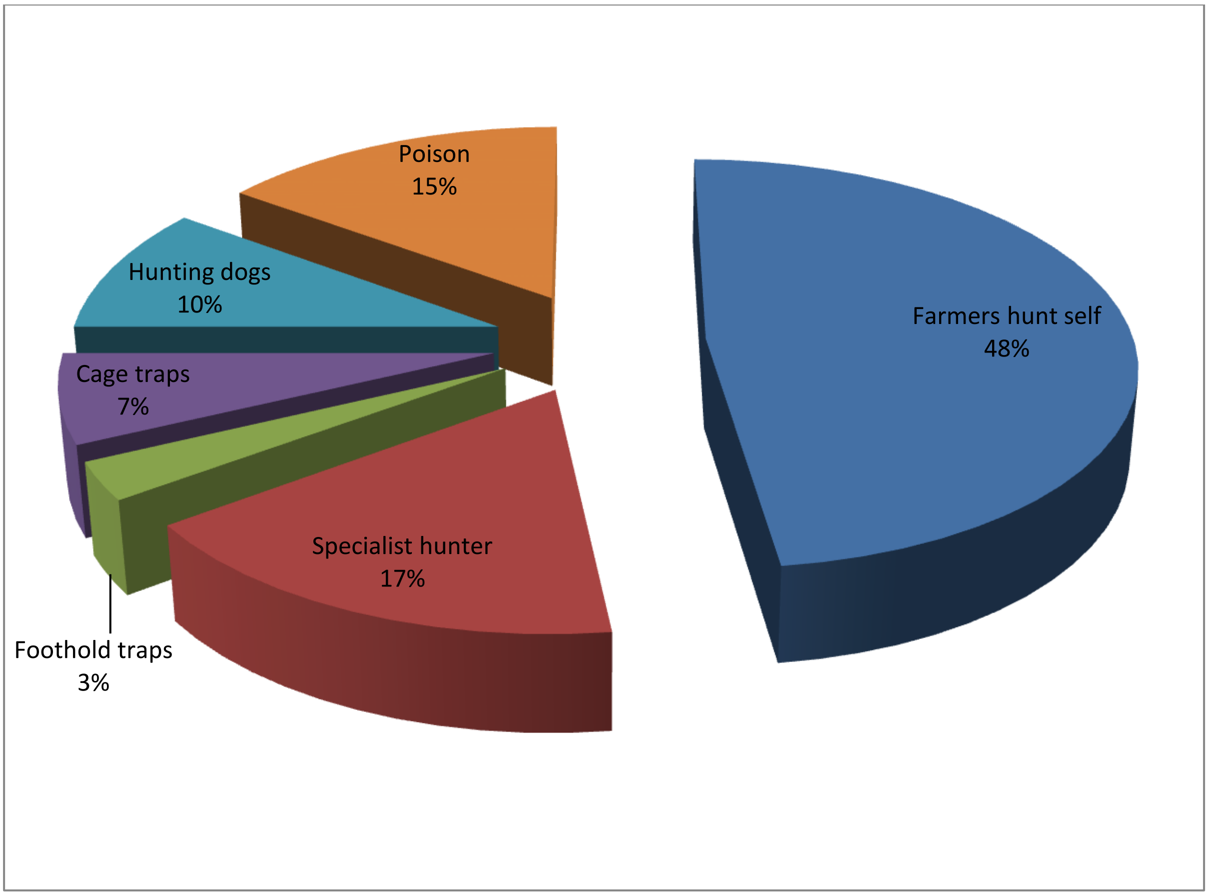

Figure: Percentage use of lethal prevention management methods in Mpumalanga.

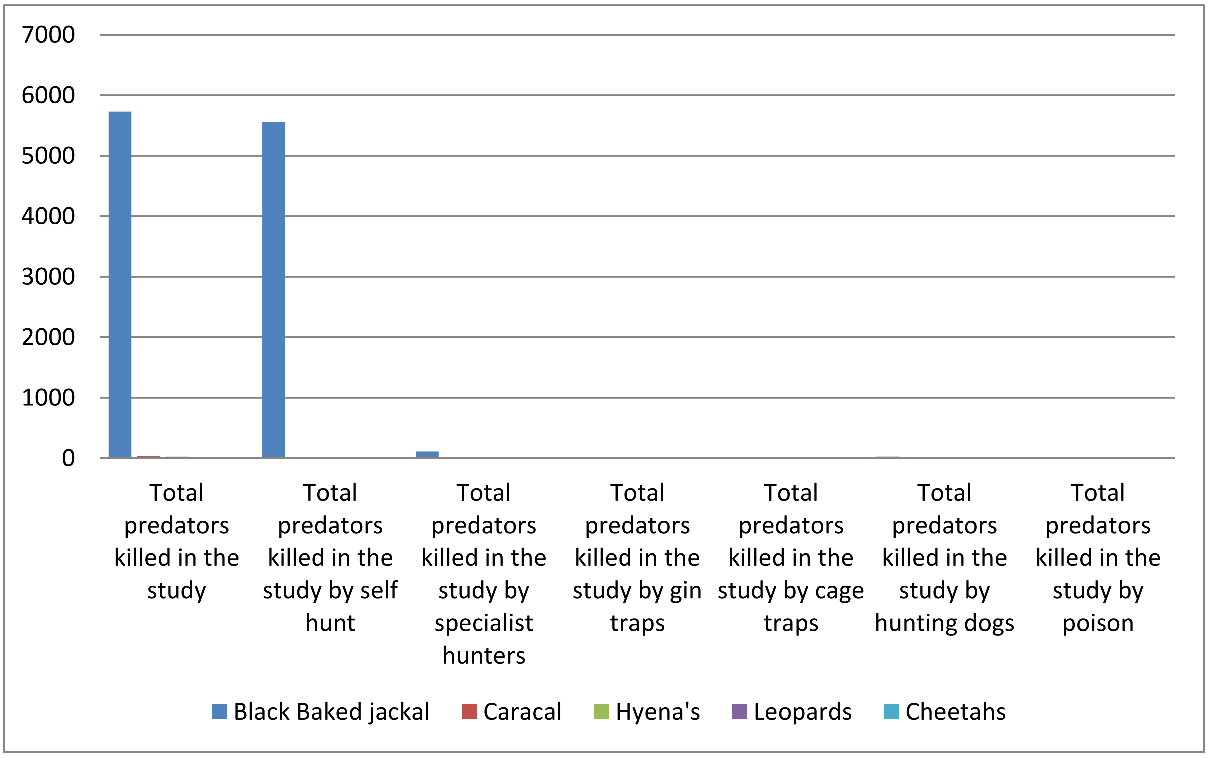

Figure: Number of predators killed with lethal methods in Mpumalanga.

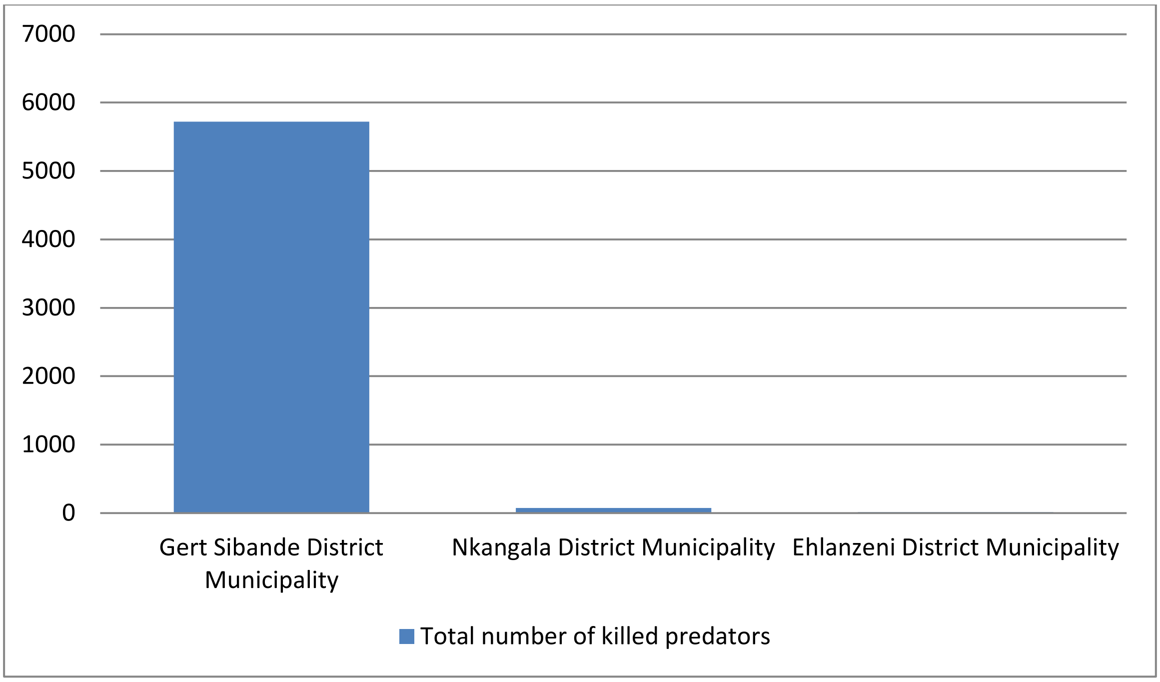

Figure: Total number of predators killed with lethal methods in Mpumalanga.

Table: The cost of non-lethal predation management in Mpumalanga

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
Gert Sibande	2 052 000	139 696	14.69	602 865	8 855 508
Nkangala	129 000	32 392	3.98	227 814	907 261
Ehlanzeni	20 000	6 990	2.86	71 122	203 496
Total	2 201 000	179 078	-	901 801	9 966 265

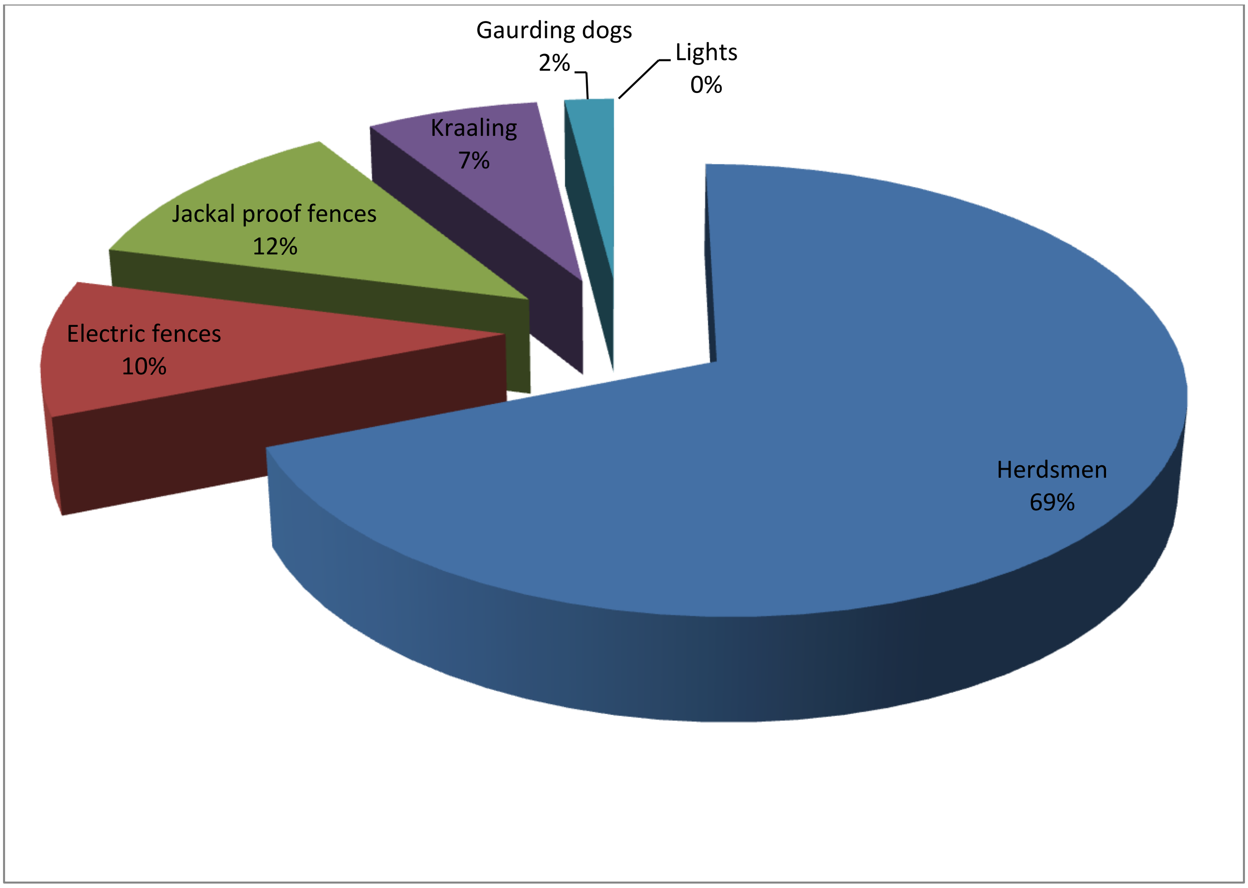

Figure: Percentage use of non-lethal management methods to prevent predation in Mpumalanga.

Table: The total direct and indirect cost of predation in Mpumalanga

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost of predation
Gert Sibande	2 912 564	8 855 508	10 275 200	22 043 272
Nkangala	798 249	907 261	11 190 400	12 895 910
Ehlanzeni	122 098	203 496	8 673 600	8 999 194
Total	3 832 911	9 966 265	30 139 200	43 938 376

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.714
Bartlett's Test of Sphericity	Approx.Chi-Square	924.337
	df	136
	Sig.	0.000

Table: Results of the Communalities

	Initial	Extraction
Calving in February	1.000	0.891
Calving in March	1.000	0.808
Calving in April	1.000	0.675
Calving in June	1.000	0.855
Calving in July	1.000	0.860
Calving in November	1.000	0.744
Calving in kraal December	1.000	0.819
Calving in the kraal	1.000	0.760
Pregnancy testing	1.000	0.669
Jackals proof fence	1.000	0.736
Gin traps	1.000	0.567
Cage traps	1.000	0.632
Hunting with dogs	1.000	0.613
Poison	1.000	0.663
Specialist hunters	1.000	0.669
Farmer himself hunts	1.000	0.704
Calving in January	1.000	0.708

Table: Percentage variance explained

Component	Rotation Sum of Squared Loadings		
	Eigen value	% of variance	Cumulative %
1	2.868	16.871	16.871
2	1.946	11.449	28.320
3	1.755	10.326	38.646
4	1.632	9.599	48.245
5	1.584	9.320	57.565
6	1.296	7.624	65.189
7	1.218	7.166	72.355

Table: Results from the Rotated Component Matrix

	Component						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Calving in March	**0.885**	0.091	0.104	0.003	-0.065	0.028	-0.009
Calving in February	**0.828**	0.305	0.177	-0.040	0.001	0.074	0.052
Calving in April	**0.789**	-0.030	0.159	0.095	-0.089	0.027	-0.091
Calving in January	**0.662**	0.487	0.093	-0.048	-0.025	0.073	0.122
Calving in November	0.081	**0.846**	0.095	0.058	-0.092	0.002	-0.031
Calving in December	0.317	**0.835**	0.088	-0.005	0.071	0.084	0.028
Calving in July	0.160	0.059	**0.894**	-0.031	-0.117	0.134	0.001

Calving in June	0.271	0.167	**0.866**	-0.018	-0.037	-0.013	-0.056
Farmer himself hunts	0.028	0.097	-0.141	**0.802**	-0.094	-0.070	-0.133
Specialist hunters	-0.005	-0.052	-0.050	**0.642**	0.166	0.463	0.098
Hunting with dogs	0.023	-0.022	0.192	**0.639**	0.195	-0.156	0.322
Poison	0.011	-0.337	-0.151	-0.249	**0.678**	-0.032	-0.063
Cage traps	-0.134	0.137	-0.096	0.152	**0.677**	0.321	-0.031
Gin traps	-0.047	0.035	0.032	0.206	**0.643**	-0.105	0.310
Calving in the kraal	0.092	0.094	0.117	-0.039	0.066	**0.849**	-0.056
Jackals proof	-0.074	0.041	-0.078	0.094	0.164	-0.066	**0.826**
Pregnancy testing	-0.331	0.077	-0.055	0.109	0.326	-0.418	**-0.519**

Table: Results of Logit regression to identify mitigating factors that affect the occurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of farm	0.101	0.482
Farmer's age	0.143	0.447
Completion of school	-0.225	0.093**
Further studies in agriculture	0.065	0.764
Member of a farmer's association	-0.088	0.758
Member of a producer's association	-0.037	0.866
Experience as a farmer	0.289	0.088**
Managerial factors		
Sizeof breeding herd	0.064	0.654

Calving in January	0.006	0.955
Calving in February	-0.008	0.844
Calving in March	-0.039	0.693
Calving in April	0.092	0.453
Calving in May	0.163	0.212
Calving in June	0.101	0.530
Calving in July	0.047	0.755
Calving in August	-0.032	0.827
Calving in September	0.079	0.737
Calving in October	0.059	0.802
Calving in November	-0.031	0.823
Calving in December	0.047	0.587
Calving on grazing land	0.123	0.374
Calving on pastures	-0.293	0.150*
Calving on crop residues	0.053	0.779
Calving in the kraal	0.119	0.461
Times counted per month	0.156	0.447
Times worked with livestock per month	-0.570	0.104*
Age at first conception	-0219	0.336
Pregnancy testing	0.198	0.038***
Dehorn	-0.086	0.599
Removal dead animals	0.148	0.639
Recording difficult birth	0.198	0.153
Sheep	0.027	0.913
Non-lethal methods		
Herdsmen	-0.242	0.207
Jackals proof	-0.477	0.141*
Electric fences	-0.060	0.673
Lights	0.016	0.951
Kraaling	0.040	0.645
Guarding animals	0.370	0.061**
Lethal methods		
Farmer himself hunts	0.483	0.071**

Specialist hunters	0.196	0.175
Gin traps	0.011	0.948
Cage traps	0.092	0.675
Hunting with dogs	0.028	0.715
Poison	0.022	0.774

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Results of Truncated regression to identify mitigating factors that affect the level of predation

	Truncated	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of the farm	0.000	0.752
Farmer's age	0.002	0.289
Completion of school	-0.001	0.070**
Further studies in agriculture	0.001	0.538
Member of a farmer's association	-0.001	0.646
Member of a producer's association	0.000	0.838
Experience as a farmer	0.003	0.107*
Managerial factors		
Size of breeding herd	0.000	0.958
Calving in January	0.000	0.946
Calving in February	0.000	0.532
Calving in March	0.000	0.546
Calving in April	0.001	0.359
Calving in May	0.001	0.165
Calving in June	0.001	0.486
Calving in July	0.000	0.728
Calving in August	0.000	0.830
Calving in September	0.002	0.507
Calving in October	0.001	0.572
Calving in November	0.000	0.971
Calving in December	0.000	0.566

Calving on grazing land	0.001	0.376
Calving on pastures	-0.002	0.177
Calving on crop residues	0.001	0.585
Calving in the kraal	0.001	0.537
Times counted per month	0.002	0.365
Times worked with livestock per month	-0.004	0.123*
Age at first conception	-0.002	0.324
Pregnancy testing	0.001	0.049***
Dehorn	-0.001	0.395
Removal of dead animals	0.001	0.628
Recording of difficult births	0.001	0.204
Sheep	0.000	0.904
Non-lethal methods		
Herdsmen	-0.001	0.370
Jackals proof	-0.004	0.131*
Electric fences	0.000	0.942
Lights	0.000	0.865
Kraaling	0.000	0.802
Guarding animals	0.002	0.062**
Lethal methods		
Farmer himself hunts	0.004	0.076**
Specialist hunters	0.001	0.197
Gin traps	0.000	0.735
Cage traps	0.000	0.859
Hunting with dogs	0.000	0.514
Poison	0.000	0.686

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Logit regression

Null Hypothesis:	**Probability (Logit)**
Completion of school does not Granger Cause predation	0.508
Experience as a farmer does not Granger Cause predation	0.088**

Calving on pastures does not Granger Cause predation	0.003****
Times worked with livestock per month does not Granger Cause predation	0.669
Pregnancy testing does not Granger Cause predation	0.163
Jackals proof does not Granger Cause predation	0.976
Guarding animals does not Granger Cause predation	0.330
Farmer himself hunts does not Granger Cause predation	0.644

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Truncated regression

Null Hypothesis:	**Probability (Truncated)**
Completion of school does not Granger Cause predation	0.999
Experience as a farmer does not Granger Cause predation	0.006****
Times worked with livestock per month does not Granger Cause predation	0.989
Pregnancy testing does not Granger Cause predation	0.825
Jackals proof does not Granger Cause predation	0.578
Guarding animals does not Granger Cause predation	0.842
Farmer himself hunts does not Granger Cause predation	0.434

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Appendix G: Northern Cape

The primary information obtained in the survey from **99 responding farmers** in the Northern Cape province.

Table: Number of farmers surveyed, land utilisation and cattle numbers in the Northern Cape

	Surveyed	Northern Cape	Percentage
Farmers	99	4 705	2.1
Head of cattle	66 050	509 475	13
Grazing land (ha)	417 953	29 089 367	1.4

Source: NDA, 2012

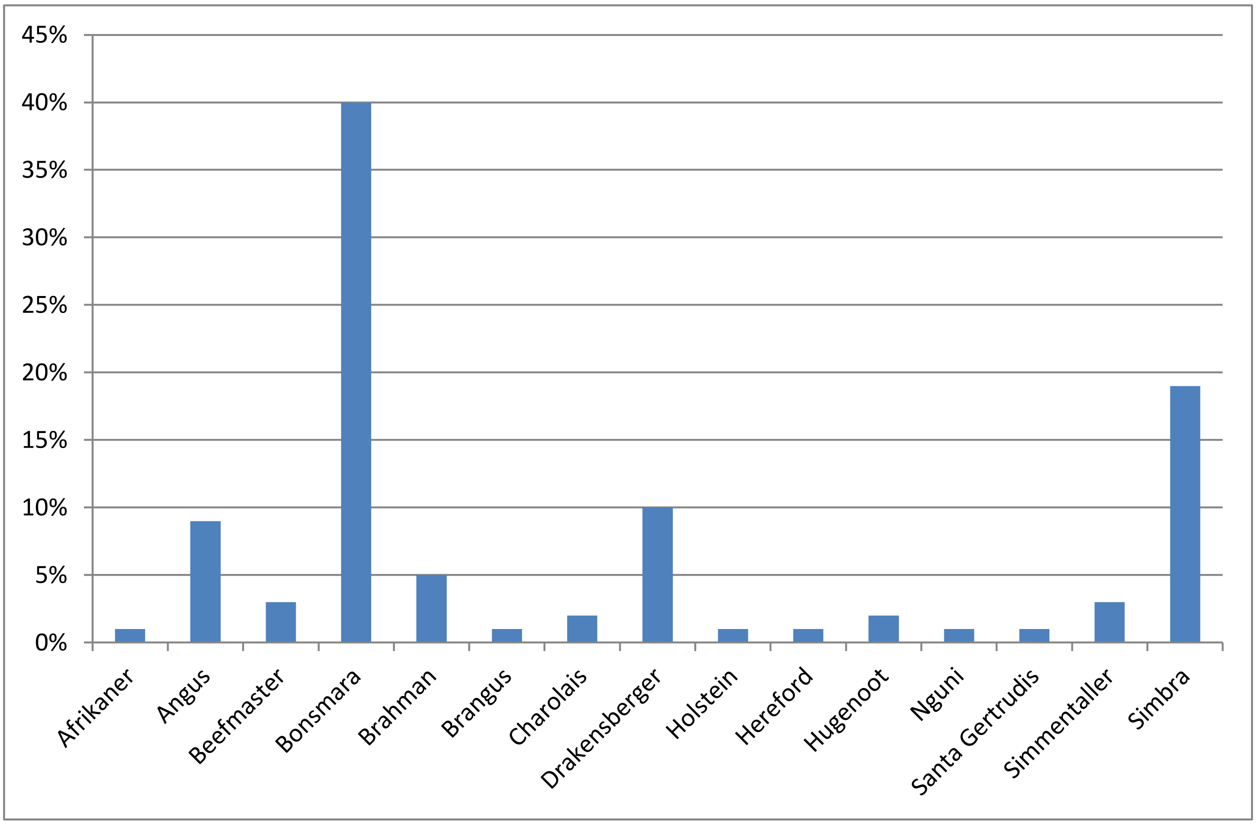

Figure: Cattle breeds of respondents surveyed in the Northern Cape.

Table: Farmers personal information in the Northern Cape province

Survey information	
Farmers average age (years)	53
Completion of school	51%
Further studies in agriculture	24%
Members of a farmer association	81%
Member of a producers association	98%
Experience as farmer (years)	26

Table: The number of cattle lost to predation in the Northern Cape

Magisterial districts	Number of cattle predated	Number of cattle surveyed	Average predation losses (%)
Namakwa	30	3 158	0.95
Pixley Ka Seme	0	2 690	0
Siyanda	9	20 192	0.04
Frances Baard	25	18 969	0.13
Johan Taolo Gaetsewe	12	21 041	0.06
Total	76	66 050	-

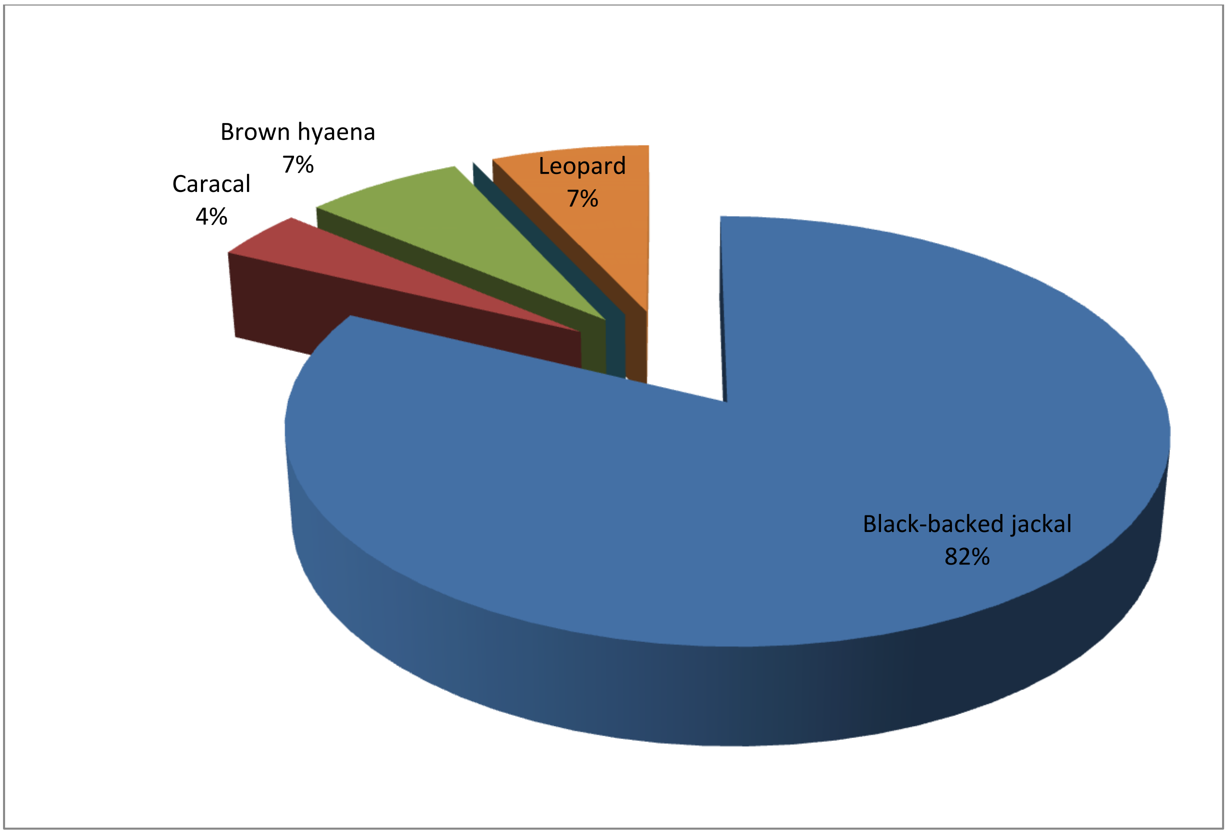

Figure: Predator species responsible for predation losses in the Northern Cape.

Table: The direct cost of predation on cattle in the Northern Cape

Magisterial district	Number of cattle in the Northern Cape	Average predation losses (%)	Losses due to predators	Unit cost per animal (R)	Cost of predation (R)
Namakwa	14 473	0.95	137	10 400	1 424 800
Pixley Ka Seme	37 357	0	0	10 400	0
Siyanda	163 330	0.04	73	10 400	759 200
Frances Baard	152 031	0.13	200	10 400	2 080 000
Johan Taolo Gaetsewe	142 284	0.06	81	10 400	842 400
Total	509 475	-	491	-	5 106 400

Table: Costs of lethal predation management in the Northern Cape

Magisterial district	Total cost in study (R)	Number of cattle in study	Lethal cost per unit (R/head)	Number of cattle in province	Total lethal cost (R)
Namakwa	13 000	3 158	4.12	14 473	59 579
Pixley Ka Seme	0	2 690	0	37 357	0
Siyanda	37 200	20 192	1.84	163 330	300 905
Frances Baard	176 000	18 969	9.28	152 031	1 410 589
Johan Taolo Gaetsewe	51 850	21 041	2.46	142 284	350 621
Total	278 050	66 050	-	509 475	2 121 694

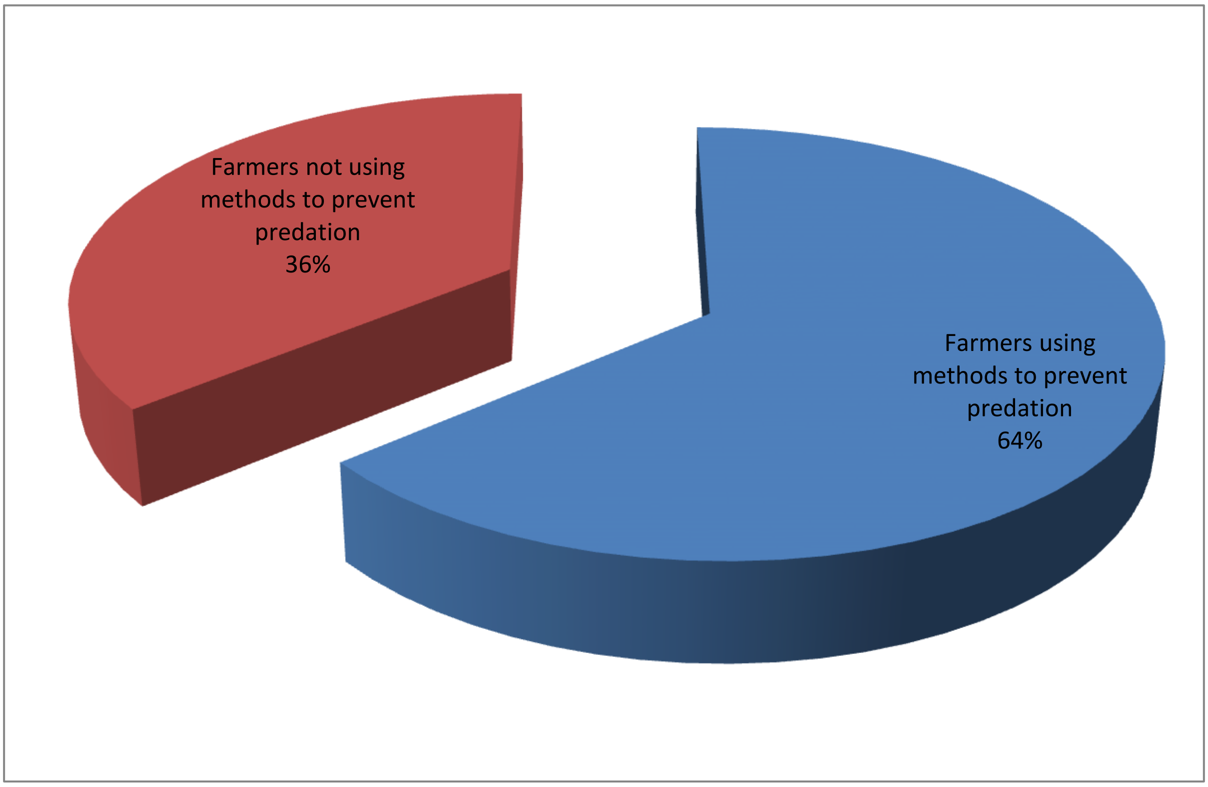

Figure: Percentage of farmers using predation management methods in the Northern Cape.

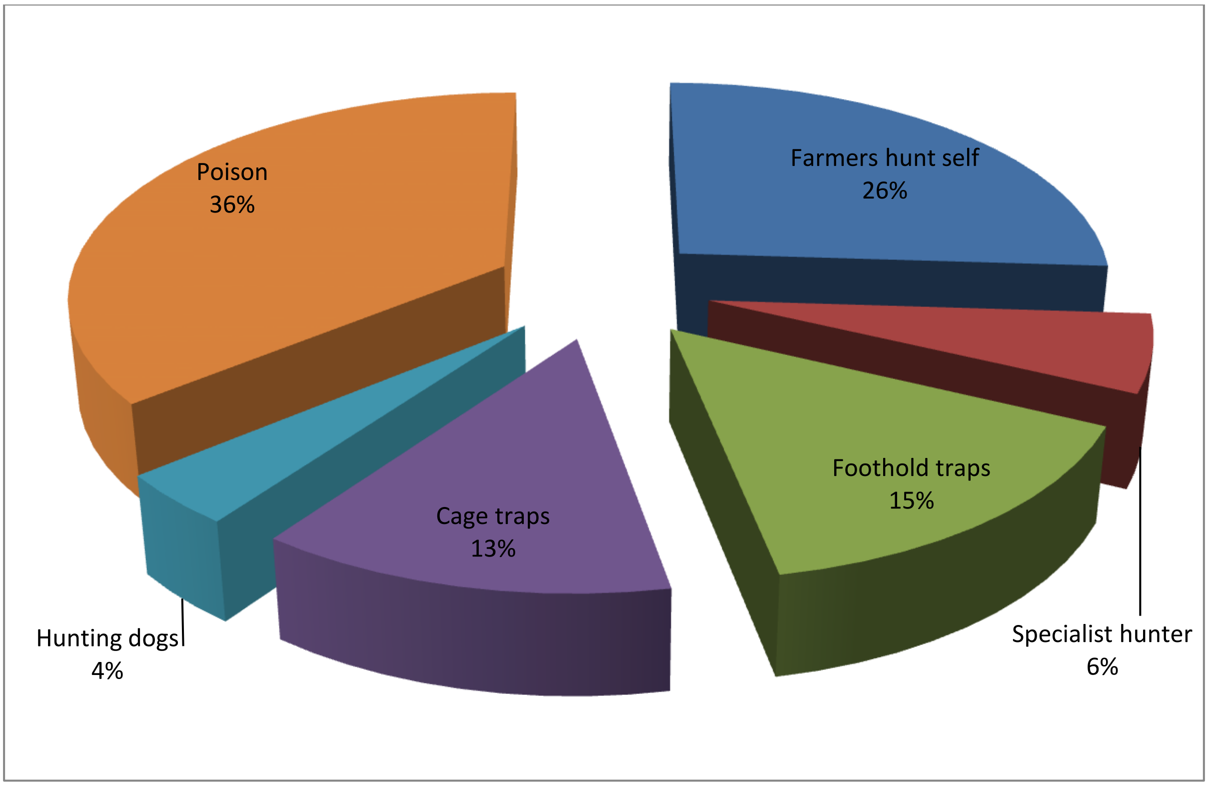

Figure: Percentage use of lethal prevention management methods in the Northern Cape.

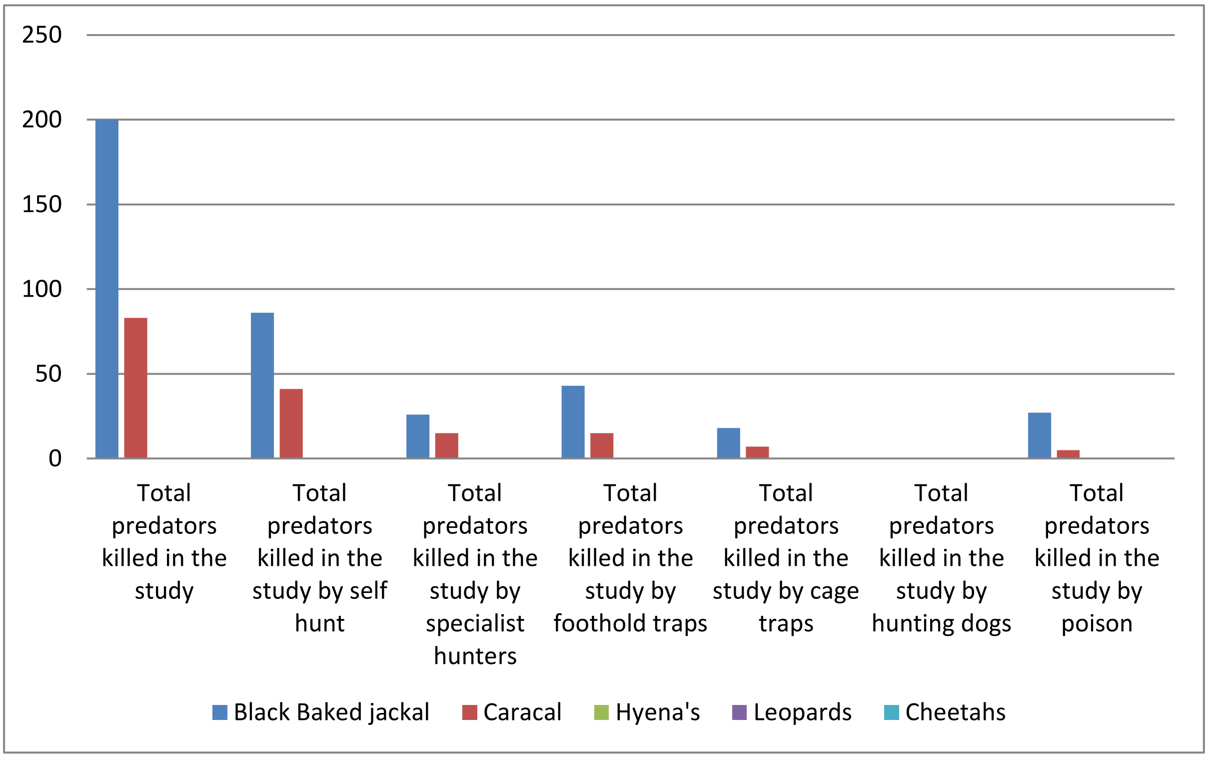

Figure: Number of predators killed with lethal methods in the Northern Cape.

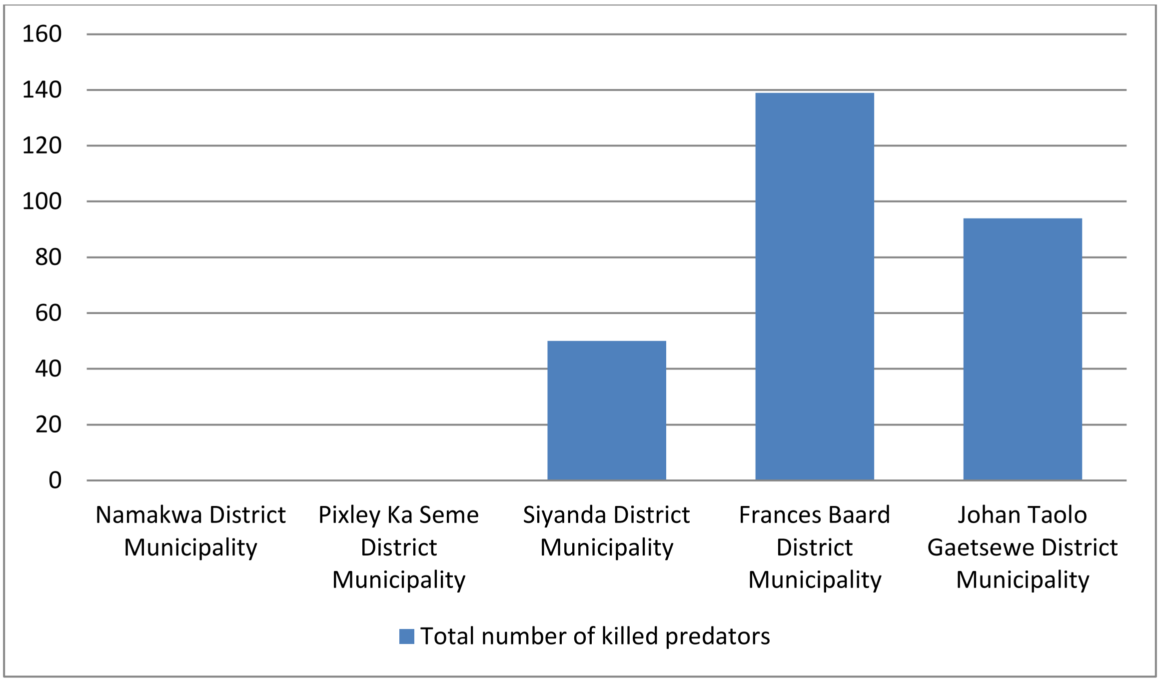

Figure: Total number of predators killed with lethal methods in the Northern Cape.

Table: The cost of non-lethal predation management in the Northern Cape

Magisterial districts	Total cost in study (R)	Number of cattle in study	Non-lethal cost per unit (R/head)	Number of cattle in province	Total non-lethal cost (R)
Namakwa	10 000	3 158	3.17	14 473	45 830
Pixley Ka Seme	0	2 690	0	37 357	0
Siyanda	782 000	20 192	38.73	163 330	6 325 478
Frances Baard	378 500	18 969	19.95	152 031	3 033 567
Johan Taolo Gaetsewe	489 500	21 041	23.26	142 284	3 310 110
Total	1 660 000	66 050	-	509 475	12 714 985

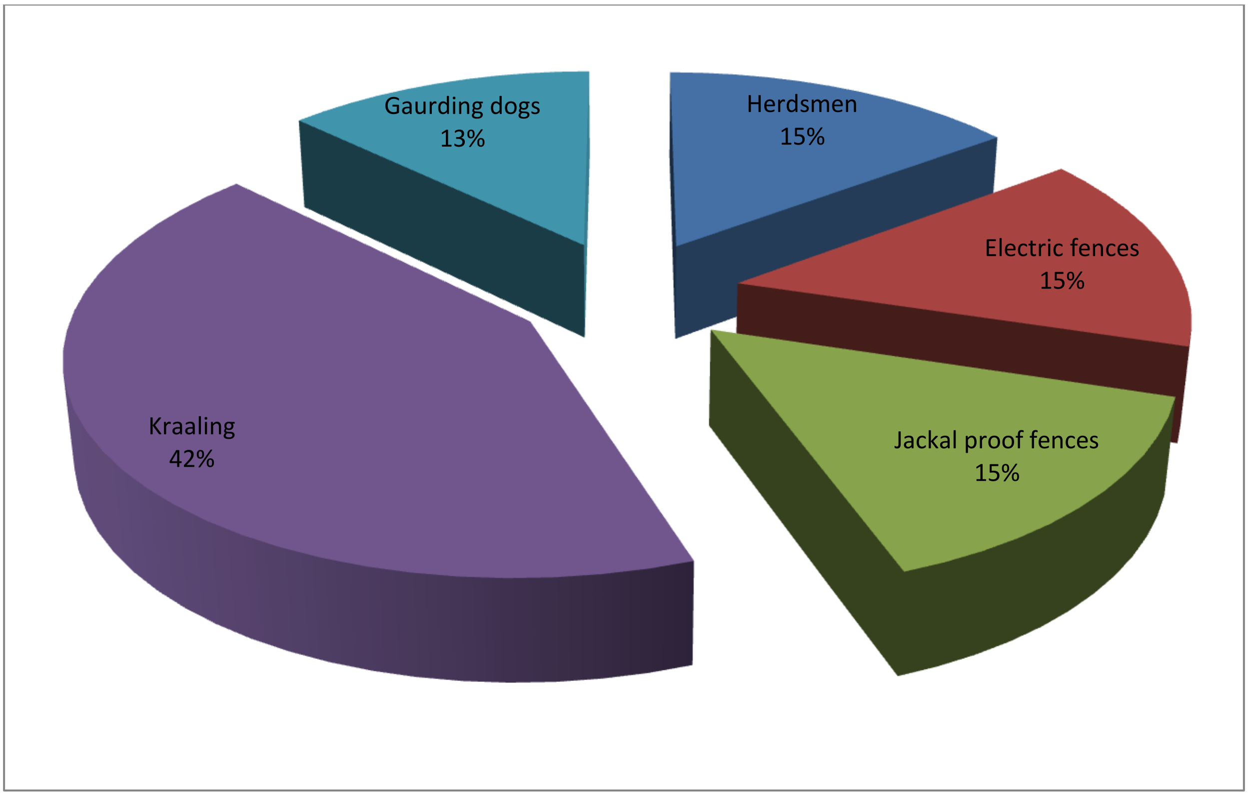

Figure: Percentage use of non-lethal methods to prevent predation in the Northern Cape.

Table: The total direct and indirect cost of predation in the Northern Cape

Magisterial districts	Total lethal cost (R)	Total non-lethal cost (R)	Total cost of predation (R)	Total direct and indirect cost
Namakwa	59 579	45 830	1 424 800	1 530 209
Pixley Ka Seme	0	0	0	0
Siyanda	300 905	6 325 478	759 200	7 385 583
Frances Baard	1 410 589	3 033 567	2 080 000	6 524 156
Johan Taolo Gaetsewe	350 621	3 310 110	842 400	4 503 131
Total	2 121 694	12 714 985	5 106 400	19 943 079

Table: Results of the KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.764
Bartlett's Test of Sphericity	Approx.Chi-Square	1387.573
	df	153
	Sig.	0.000

Table: Results of the Communalities

	Initial	Extraction
Calving in January	1.000	0.872
Calving in February	1.000	0.902
Calving in March	1.000	0.863
Calving in April	1.000	0.814
Calving in May	1.000	0.848
Calving in June	1.000	0.894
Calving in July	1.000	0.863
Calving in August	1.000	0.754
Calving in October	1.000	0.782
Calving in November	1.000	0.852
Calving in December	1.000	0.754
Caving on crop residue	1.000	0.747
Calving in the kraal	1.000	0.883
Age at first conception	1.000	0.666
Removal of dead animals	1.000	0.592
Herdsmen	1.000	0.745
Kraaling	1.000	0.876
Guarding animals	1.000	0.769

Table: Percentage variance explained

Component	Rotation Sum of Squared Loadings		
	Eigen value	% of variance	Cumulative %
1	6.120	34.001	34.001
2	2.450	13.612	47.613
3	1.754	9.746	57.358
4	1.590	8.833	66.192
5	1.338	7.435	73.627
6	1.222	6.789	80.416

Table: Results from the Rotated Component Matrix

	-0.114Component					
	1	**2**	**3**	**4**	**5**	**6**
Calving in March	**0.915**	-0.114	0.014	0.052	0.082	0.050
Calving in February	**0.896**	-0.060	0.007	-0.098	-0.250	0.152
Calving in January	**0.880**	0.118	0.014	-0.078	-0.215	0.178
Calving in July	**0.877**	0.239	0.095	-0.094	0.128	0.050
Calving in June	**0.856**	0.355	-0.011	-0.101	0.147	0.049
Calving in August	**0.827**	-0.119	0.089	-0.087	0.196	-0.040
Calving in May	**0.796**	0.439	-0.037	-0.110	0.084	0.044
Calving in April	**0.793**	0.370	-0.030	0.012	0.218	0.018

Calving in November	0.107	**0.904**	0.117	-0.101	-0.010	-0.027
Calving in October	0.083	**0.789**	0.097	0.140	0.325	-0.136
Calving in December	0.384	**0.628**	0.085	-0.102	-0.172	0.406
Calving in the kraal	0.114	0.055	**0.929**	-0.022	0.041	-0.040
Kraaling	-0.048	0.145	**0.912**	-0.093	-0.050	0.096
Guarding animals	-0.083	0.006	-0.038	**0.871**	0.005	-0.052
Herdsmen	-0.105	-0.044	-0.067	**0.849**	-0.004	0.085
Age at first conception	-0.033	-0.059	-0.003	0.008	**-0.813**	-0.024
Removal of death animals	0.227	0.156	-0.035	-0.042	**0.536**	0.475
Calving on crop residues	-0.071	0.077	-0.047	-0.054	-0.071	**-0.852**

Table: Results of Logit regression to identify mitigating factors that affect the occurrence of predation

	Logit	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of the farm	0.034	0.867
Farmer's age	-0.235	0.391
Completion of school	0.534	0.066**
Further studies in agriculture	0.184	0.407
Member of a farmer's association	-0.322	0.251
Member of a producer's association	-0.203	0.385

Experience as a farmer	0.030	0.891
Managerial factors		
Size of breeding herd	0.228	0.505
Calving in January	0.128	0.635
Calving in February	0.166	0.571
Calving in March	0.090	0.687
Calving in April	0.136	0.340
Calving in May	0.154	0.238
Calving in June	-0.036	0.796
Calving in July	0.016	0.899
Calving in August	0.074	0.645
Calving in September	0.123	0.550
Calving in October	0.185	0.645
Calving in November	0.342	0.345
Calving in December	0.043	0.660
Calving on grazing land	0.498	0.120*
Calving on pastures	-0.562	0.159
Calving on crop residues	-0.058	0.785
Calving in the kraal	0.313	0.132*
Times counted per month	0.387	0.059**
Times worked with livestock per month	-0.173	0.514
Age at first conception	0.460	0.127*
Pregnancy testing	0.624	0.094**
Dehorn	0.013	0.966
Removal of dead animals	-0.321	0.273
Recording of difficult births	0.283	0.401
Sheep	-0.062	0.861
Non-lethal methods		
Herdsmen	-0.003	0.987
Jackals proof	-0.716	0.149*
Electric fences	0.335	0.571
Lights	0.062	0.748
Kraaling	0.185	0.218

Guarding animals	0.066	0.734
Lethal methods		
Farmer himself hunts	0.359	0.143*
Specialist hunters	0.175	0.447
Gin traps	0.392	0.136*
Cage traps	-0.183	0.613
Hunting with dogs	0.096	0.735
Poison	-0.034	0.924

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table: Results of Truncated regression to identify mitigating factors that affect the level of predation

	Truncated	
Variables	**STD Beta**	**P value**
Socio economic factors		
Size of the farm	-0.001	0.145*
Farmer's age	0.000	0.626
Completion of school	0.002	0.001****
Further studies in agriculture	0.000	0.197
Member of a farmer's association	0.000	0.426
Member of a producer's association	0.000	0.483
Experience as farmer	0.001	0.030***
Managerial factors		
Size of breeding herd	0.000	0.889
Calving in January	0.000	0.478
Calving in February	0.000	0.443
Calving in March	0.000	0.501
Calving in April	0.001	0.004****
Calving in May	0.001	0.006****
Calving in June	0.000	0.808
Calving in July	0.000	0.850
Calving in August	0.000	0.443
Calving in September	0.001	0.120*

Calving in October	0.002	0.024***
Calving in November	0.002	0.016***
Calving in December	0.000	0.357
Calving on grazing land	0.001	0.052**
Calving on pastures	-0.001	0.097**
Calving on crop residues	0.000	0.995
Calving in the kraal	0.001	0.032***
Times counted per month	0.001	0.002****
Times worked with livestock per month	0.000	0.801
Age at first conception	0.001	0.013***
Pregnancy testing	0.002	0.004****
Dehorn	0.001	0.004****
Removal of dead animals	0.000	0.442
Recording of difficult birth	0.002	0.032***
Sheep	0.001	0.369
Non-lethal methods		
Herdsmen	-0.001	0.009****
Jackals proof	-0.001	0.037***
Electric fences	0.002	0.319
Lights	0.000	0.355
Kraaling	0.001	0.068**
Guarding animals	0.000	0.376
Lethal methods		
Farmer himself hunts	0.001	0.002****
Specialist hunters	0.001	0.004****
Gin traps	0.002	0.022***
Cage traps	0.001	0.324
Hunting with dogs	0.001	0.044***
Poison	0.000	0.731

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Logit regression

Null Hypothesis:	Probability (Logit)
Completion of school does not Granger Cause predation	0.339
Calving on grazing land does not Granger Cause predation	0.772
Calving in the kraal does not Granger Cause predation	0.228
Times counted per month does not Granger Cause predation	0.160
Age at first conception does not Granger Cause predation	0.042***
Pregnancy testing does not Granger Cause predation	0.600
Jackals proof does not Granger Cause predation	0.392
Farmer himself hunts does not Granger Cause predation	0.834
Gin traps does not Granger Cause predation	0.890

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.

Table 4.13: Pairwise Granger Causality test of significant variables from Truncated regression

Null Hypothesis:	Probability (Truncated)
Size of the farm does not Granger Cause predation	0.746
Completion of school	0.349
Experience as a farmer	0.204
Calving in April	0.161
Calving in May	0.202
Calving in September	0.209
Calving in October	0.564
Calving in November	0.493
Calving on grazing land	0.898
Calving on pastures	0.865
Calving in the kraal	0.793

Times counted per month	0.247
Age at first conception	0.822
Pregnancy testing	0.275
Dehorn	0.457
Recording of difficult births	0.826
Herdsmen	0.081**
Jackals proof	0.153
Kraaling	0.934
Farmer himself hunts	0.667
Specialist hunters	0.119*
Gin traps	0.596
Hunting with dogs	0.424

Note: ****, ***, **, and * indicate statistical significance of 1%, 5%, 10% and 15% respectively.