THE ECONOMIC IMPACT OF PREDATION IN THE WILDLIFE RANCHING INDUSTRY IN LIMPOPO, SOUTH AFRICA

BY ANCHE SCHEPERS

Submitted in fulfilment of the requirements for the degree

M.Sc. Agric.

FACULTY OF NATURAL AND AGRICULTURAL SCIENCES

DEPARTMENT OF AGRICULTURAL ECONOMICS

UNIVERSITY OF THE FREE STATE

BLOEMFONTEIN

JANUARY 2016

DECLARATION

I declare that this dissertation for the Magister Scientiae (M.Sc. Agric.) degree in Agricultural Economics within 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 a 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.

Anche Schepers

Bloemfontein

January 2016

ACKNOWLEDGEMENTS

I would like to thank all who made this study possible, especially the following persons and institutions:

Wildlife Ranching South Africa (WRSA) and the Red Meat Research and Development (RMR&D), who provided the funds to complete the study, as well as the large number of wildlife ranchers who participated voluntarily in the study.

My supervisor, Prof. HO de Waal, Department of Animal, Wildlife and Grassland Sciences, University of the Free State (UFS), for his knowledge in the field of study. My co-supervisors in the Department of Agricultural Economics; Mr. Walter van Niekerk, for his time, encouragement and friendship and Dr. Nicky Matthews for all her help, support and kindness.

My colleagues and friends in the Department of Agriculture at the University of the Free State, especially Dr. Dirk Strydom, Ester Monteiro, Marcill Venter, Luan van der Walt and Ruan Schutte; and the administrative staff namely Louise Hoffman, Chrizna van der Merwe and Ina Combrinck.

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

My parents (Fouchè and Ansie Schepers), brother and sister for their love, support and encouragement, without them none of this would have been possible.

Most importantly I want to give thanks to God for giving me the talent, wisdom and strength to complete this study.

ABSTRACT

THE ECONOMIC IMPACT OF PREDATION IN THE WILDLIFE RANCHING INDUSTRY IN LIMPOPO, SOUTH AFRICA

by

Anche Schepers

Degree: M.Sc. Agric.

Department: Agricultural Economics

Institution: University of the Free State, Bloemfontein

Supervisor: Prof. HO de Waal (Department of Animal, Wildlife and Grassland Sciences)

Co-supervisors: Mr. H.N. van Niekerk

Dr. N. Matthews

ABSTRACT

South Africa has always been rich in wildlife species, but the population size has varied greatly over the past century. The incentive provided by the Game Theft Act, Act 105 of 1991 as amended, allowed individuals to engage in natural resource based private enterprises and gave rise to the rapid development of the wildlife industry. Losses due to

predation is a large problem, not only in the small and large livestock industries, but losses have also been incurred in the wildlife ranching industry. There is not much known regarding wildlife numbers in South Africa, due to the difficulty in counting wildlife. Even though there are uncertainties regarding wildlife numbers, the number of animals sold on game auctions increased by 16.7% per year since 2009. The wildlife industry grew rapidly the past decade and is currently the sixth largest agricultural commodity in South Africa; every year more agricultural land previously devoted to livestock or crops are devoted to wildlife ranching.

This detailed study was conducted in all the provinces of South Africa. The dissertation focussed on the situation in the Limpopo province; basic information regarding the other Provinces of South Africa are included in **Appendices**.

The primary objective of the dissertation was to determine the economic implication of predation on the wildlife ranching industry of the Limpopo province, South Africa. This was not an easy task because of the large variety of wildlife species and because it is difficult to count wildlife.

The wildlife species (antelope) were divided into three groups based on the reported predation incurred on wildlife ranches, namely: large antelope species, small antelope species and scarce species/colour variant antelope. The direct cost is associated with the number of animals lost due to predation, this ZAR value was calculated per hectare for each of the species defined in the three groups. The indirect cost is the total cost associated with the prevention and control of predation. The total indirect cost was calculated as ZAR 26.15/ha.

The results obtained by calculating losses for the defined three scenarios provided an indication of how large the predation losses are on wildlife ranches. Calculating the total cost for the entire wildlife sector may lead to over or underestimations; therefore the total cost were calculated/ha.

Any wildlife rancher can use the baseline information and calculate his/her own financial losses; for example: a wildlife rancher who keeps nyalas on 5 000 ha can calculate his/her estimated total cost to be ZAR 593 765/year. A wildlife rancher who keeps blesbok on 12 000 ha can incur a total cost of ZAR 668 103/year and a wildlife rancher who keeps black impala and Livingston eland on 6 000 ha can calculate his/her total cost to be ZAR 11 957 637/year. It was concluded from these three scenarios that the losses due to predation, as caculated in all three groups, were large; this is in line with the hypothesis.

Factors that influence the occurrence and the level of predation were also determined by using Probit and Truncated regression models, respectively. The variables affecting the occurrence and the variables affecting the level of predation were different, and the variables affecting the three different groups varied as well.

Propensity Score Matching was used to determine whether the method of counting wildlife has an effect on the level of predation. The method of counting had an effect on the level of predation on large antelope species and scarce species/colour variants, but not on small antelope species.

This dissertation provides information for wildlife ranchers to calculate the total cost due to predation on their own specific wildlife ranches. They can improve their management practices and choose appropriate control methods, whether non-lethal, methods assisting wildlife ranchers or lethal methods. They can also view and adopt the more appropriate method to count their wildlife species.

List of key terms

1. Predation
2. Wildlife ranching
3. Large antelope species
4. Small antelope species
5. Scarce species/colour variant antelope
6. Direct cost of predation
7. Indirect cost of predation
8. Factors influencing predation
9. Propensity score matching

Table of Contents

TITLE PAGE I
DECLARATION II
ACKNOWLEDGEMENTS III
ABSTRACT IV
LIST OF KEY TERMS VII
TABLE OF CONTENTS VIII
LIST OF FIGURE XIII
LIST OF TABLES XIV

CHAPTER 1

Introduction

1.1 BACKGROUND 1
1.2 PROBLEM STATEMENT 3
1.3 MOTIVATION FOR THE DISSERTATION 4
1.4 OBJECTIVES 5
1.4.1 PRIMARY OBJECTIVE 5
1.4.2 SECONDARY OBJECTIVES 5
1.5 DISSERTATION OUTLINE 6

CHAPTER 2
Literature Review

2.1 INTRODUCTION 8
2.2 GLOBAL PREDATION 8
2.3 SOUTH AFRICAN WILDLIFE RANCHING INDUSTRY 9
2.4 PREDATION IN SOUTH AFRICA 10
2.4.1 BLACK-BACKED JACKAL (*CANIS MESOMELAS*) 13
2.4.2 CARACAL (*CARACAL CARACAL*) 13
2.4.3 LEOPARD (*PANTHERA PARDUS*) 14
2.4.4 CHEETAH (*ACINONYX JUBATUS*) 15
2.4.5 BROWN HYAENA (*PARAHYEANA BRUNNEA*) 15
2.5 FACTORS INFLUENCING PREDATION 16
2.5.1 ENVIRONMENT 16
2.5.2 MANAGEMENT 18
2.5.3 GOVERNMENT REGULATIONS 18
2.6 SOUTH AFRICAN CONTROL METHODS 20
2.6.1 NON-LETHAL AND LETHAL CONTROL METHODS 21
2.7 OCCURRENCE VERSUS LEVEL OF PREDATION 22
2.8 COST ANALYSIS 23
2.8.1 DIRECT COST 23
2.8.2 INDIRECT COST 24
2.8.3 COST-EFFECTIVENESS OF CONTROL METHODS 25
2.9 SUMMARY OF RESEARCH 26

CHAPTER 3

Methodology

3.1 INTRODUCTION 28
3.2 RESEARCH AREA 28
3.3 SAMPLING 30
3.4 QUESTIONNAIRE AND DATA COLLECTION 32
3.5 PROCEDURE 34
3.5.1 QUANTIFYING PREDATION LOSSES 34
3.5.2 IDENTIFYING FACTORS AFFECTING PREDATION 36
3.5.2.1 OCCURRENCE AND LEVEL OF PREDATION 36
3.5.3 PROPENSITY SCORE MATCHING 39
3.6 VARIABLES HYPOTHESISED TO INFLUENCE PREDATION 42

CHAPTER 4

Results

4.1 INTRODUCTION 47
4.2 DESCRIPTIVE STATISTICS OF THE LIMPOPO PROVINCE AND THE WILDLIFE RANCHERS 47
4.3 ENUMERATOR'S PERSONAL OPINION 49
4.4 THE COST OF PREDATION IN THE LIMPOPO PROVINCE 52
4.4.1 DIRECT COST OF PREDATION IN THE LIMPOPO PROVINCE 52
4.4.2 INDIRECT COST OF PREDATION MANAGEMENT IN THE LIMPOPO PROVINCE 56
4.5 FACTORS INFLUENCING PREDATION IN THE LIMPOPO PROVINCE OF SOUTH AFRICA 60
4.5.1 PREDATION ON LARGE ANTELOPE SPECIES 61
4.5.1.1 OCCURRENCE OF PREDATION OF LARGE ANTELOPE SPECIES 63
4.5.1.2 LEVEL OF PREDATION ON LARGE ANTELOPE SPECIES 63
4.5.2 PREDATION ON SMALL ANTELOPE SPECIES 64

4.5.2.1 OCCURRENCE OF PREDATION OF SMALL ANTELOPE SPECIES 64
4.5.2.2 LEVEL OF PREDATION ON SMALL ANTELOPE SPECIES.......... 66
4.5.3 PREDATION ON SCARCE/COLOUR VARIANT ANTELOPE 66
4.5.3.1 OCCURRENCE OF PREDATION ON SCARCE SPECIES/COLOUR VARIANT ANTELOPE 66
4.5.3.2 LEVEL OF PREDATION ON SCARCE SPECIES/COLOUR VARIANT ANTELOPE 68
4.6 PROPENSITY SCORE MATCHING.......... 69
4.6.1 LARGE ANTELOPE SPECIES 69
4.6.2 SMALL ANTELOPE SPECIES.......... 71
4.6.3 SCARCE SPECIES/COLOUR VARIANTS 72
4.7 WHAT DOES THIS MEAN FOR THE WILDLIFE RANCHER?.......... 73

CHAPTER 5

Summary & Conclusion

5.1 INTRODUCTION.......... 76
5.2 MEETING THE OBJECTIVES OF THIS DISSERTATION 76
5.2.1 ESTIMATING THE DIRECT LOSSES AND QUANTIFYING THE INDIRECT LOSSES OF WILDLIFE DUE TO PREDATION 76
5.2.2 FACTORS THAT INFLUENCE THE OCCURRENCE AND LEVEL OF PREDATION 79
5.2.3 PROPENSITY SCORE MATCHING.......... 81
5.3 LIMITATIONS OF THE STUDY.......... 81
5.4 RECOMMENDATIONS.......... 82

REFERENCES 83
APPENDIX A: NORTHWEST 94
APPENDIX B: FREE STATE.. 104
APPENDIX C: EASTERN CAPE.. 114
APPENDIX D: KWA-ZULU NATAL 121
APPENDIX E: MPUMALANGA.. 127
APPENDIX F: NORTHERN CAPE 133
APPENDIX G: WESTERN CAPE 140
APPENDIX H: COMMON AND SCIENTIFIC NAMES AND AUCTION PRICES OF WILDLIFE SPECIES ... 146

List of Figures

Figure 3.1 Limpopo Province of South Africa 29
Figure 4.1 Predators implicated for losses on large antelope species on wildlife ranches of WRSA members in the Limpopo province 54
Figure 4.2 Predators implicated for losses on small antelope species on wildlife ranches of WRSA members in the Limpopo province 55
Figure 4.3 Predators implicated for losses on scarce species/colour variant antelope on wildlife ranches of WRSA members in the Limpopo province 55
Figure 4.4 Percentage of WRSA members using predation management methods in the Limpopo province 57
Figure 4.5 Number of WRSA members using lethal control methods to control predators in the Limpopo province 57
Figure 4.6 Percentage of people responsible for managing predation on the wildlife ranches of WRSA members in the Limpopo province 58
Figure 4.7 Number of WRSA members using non-lethal control methods and methods assisting wildlife ranchers to manage predation in the Limpopo province 59

List of Tables

TABLE 2.1 TYPES OF CONTROL METHODS 21
TABLE 3.1 NUMBER AND DISTRIBUTION OF MEMBERS OF WILDLIFE RANCHING SOUTH AFRICA AND THE ADJUSTED PROPORTION OF RESPONDENTS SELECTED FINALLY FOR THE SURVEY........ 32
TABLE 3.2 WILDLIFE RANCHER AND RANCHER'S PERCEPTION VARIABLES HYPOTHESISED TO INFLUENCE PREDATION AND THE EXPECTED INFLUENCE 43
TABLE 3.3 PHYSICAL ATTRIBUTES OF THE WILDLIFE RANCHES AND MANAGERIAL FACTOR VARIABLES HYPOTHESISED TO INFLUENCE PREDATION AND THE EXPECTED INFLUENCE........ 44
TABLE 3.4 CONTROL OR PREVENTATIVE METHOD VARIABLES HYPOTHESISED TO INFLUENCE PREDATION AND THE EXPECTED INFLUENCE........ 45
TABLE 4.1 NUMBER OF WILDLIFE RANCHERS SURVEYED AND THE HECTARES UTILISED IN THE LIMPOPO PROVINCE 48
TABLE 4.2 OPTIONS USED BY WILDLIFE RANCHERS TO ESTABLISH THE NUMBERS OF WILDLIFE IN THE LIMPOPO PROVINCE........ 48
TABLE 4.3 THREE DEFINED GROUPS OF ANTELOPE SPECIES 49
TABLE 4.4 A SUMMARY OF AVERAGE HECTARES AND AVERAGE LOSSES OF ANTELOPE CALCULATED FOR THE LIMPOPO PROVINCE 53
TABLE 4.5 RESULTS OF THE TOBIT AND DOUBLE HURDLE MODEL TO IDENTIFY VARIABLES THAT AFFECT THE OCCURRENCE AND LEVEL OF PREDATION ON LARGE SPECIES 62
TABLE 4.6 RESULTS OF THE TOBIT AND DOUBLE HURDLE MODEL TO IDENTIFY VARIABLES THAT AFFECT THE OCCURRENCE AND LEVEL OF PREDATION ON SMALL SPECIES 65
TABLE 4.7 RESULTS OF THE TOBIT AND DOUBLE HURDLE MODEL TO IDENTIFY VARIABLES THAT AFFECT THE OCCURRENCE AND LEVEL OF PREDATION ON SCARCE SPECIES/COLOUR VARIANTS........ 67
TABLE 4.8 T-TEST OF LARGE ANTELOPE SPECIES 69
TABLE 4.9 AVERAGE EFFECT OF TREATMENT ON THE TREATED (ATT) ESTIMATION WITH MATCHING METHODS (LARGE SPECIES)........ 70
TABLE 4.10 T-TEST OF SMALL ANTELOPE SPECIES 71
TABLE 4.11 T-TEST OF SCARCE SPECIES/COLOUR VARIANTS........ 72
TABLE 4.12 AVERAGE EFFECT OF TREATMENT ON THE TREATED (ATT) ESTIMATION WITH MATCHING METHODS (SCARCE SPECIES/COLOUR VARIANTS) 73
TABLE 5.1 TOTAL COST DUE TO PREDATION FOR A SELECTION OF ANTELOPE REPORTED IN THIS DISSERTATION 77

CHAPTER 1
Introduction

1.1 BACKGROUND

South Africa has always been inhabited by wildlife, but the population size has fluctuated greatly over the over the past century (Du Toit, Meissner & Van Niekerk, 2013). Important changes regarding the conditional ownership of wildlife by individuals on private properties were made in 1991 (Reyneke, 2015). The incentive provided by the Game Theft Act, Act 105 of 1991 as amended, allowed individuals to engage in natural resource based private enterprises and gave rise to rapid development of game farms, also known as wildlife ranches, in South Africa and in a relatively short period of time it became the wildlife ranching industry. The number of wildlife ranches in South Africa grew steadily from 2 280 in 1980 to currently more than 10 000 (Du Toit *et al*., 2013; Dry, 2011; 2015). The 10 000 privately owned wildlife ranches comprise more than 20 million ha, which is about three times the size of the 7.5 million ha government protected areas (Dry, 2011).

Less certainty exists regarding wildlife numbers within South Africa; Du Toit *et al*. (2013) alluded to the large variation in wildlife population numbers by citing several reports, some being as high as 18.6 million head of wildlife on privately owned properties. However, Du Toit *et al*. (2013) based their calculations of direct greenhouse emissions of the wildlife ranching industry in South Africa on an estimated 2.991 million head of wildlife on the 20.5 million ha privately owned wildlife ranches.

Despite uncertainty regarding the actual number of wildlife on privately owned properties, the number of animals sold at game auctions increased by 16.7% per year since 2009, the annual turnover at auctions increased with 35.8% and wildlife ranching has become the sixth largest agricultural commodity in South Africa (ABSA, 2015).

A large part of South Africa comprises arid and semi-arid natural pasture (veld), which is best suited as food source for herbivorous animals such as ruminants (De Waal, 1990). Therefore, livestock farming and wildlife ranching activities are practised on comparable natural resources, often as neighbours or on the same property. Thus, it can be assumed that livestock farming and wildlife ranching will also be affected by the same environmental factors, including the effects of predation (De Waal, 2015). Information is not readily available, but it has been suggested that the wildlife ranching industry is, similar to the livestock industry, negatively affected by predation (Avenant, De Waal & Combrinck, 2006; Bergman, De Waal, Avenant, Bodenchuk, Marlow & Dale, 2013; Cilliers, 2006; De Waal, 2009a), severe losses of wildlife may be incurred.

In a “first for South Africa” a study by Strauss (2009) reported that predation on sheep flocks on farm level at the Glen Agricultural Institute in the Free State province constituted 72% of the total annual financial losses, diseases 2%, metabolic disorders or accidents 20% and stock theft only 6%. These losses were incurred despite the use of non-lethal and lethal methods to control predators. The study by Strauss (2009) was only the third report of the devastating impact of predation on sheep flocks at research and academic institutions.

While Strauss (2009) only determined the physical losses due to predation Van Niekerk (2010) investigated the economic implication of predation on the small livestock industry in South Africa and estimated that the total cost of predation in the five major small livestock producing areas, namely the Free State, Mpumalanga, Northern Cape, Eastern Cape and Western Cape provinces were ZAR 1 390 million. The study of van Niekerk (2010) served as basis for a series of building blocks of predation studies in South Africa. Badenhorst (2014) used Van Niekerk’s (2010) approach to investigate the direct and indirect cost of predation on large livestock, mainly focusing on beef cattle, in seven provinces of South Africa. Losses were estimated at more than ZAR 393 million for the participating provinces. The indirect cost of predation contributed to the research by establishing an important cost component that is often overlooked when losses due predation are calculated; these losses estimated are extremely high and requires action in the form of predation management to reduce losses.

The studies by Van Niekerk (2010) and Badenhorst (2014) indicated that caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) are the two major damage causing animals in the small and large livestock industries in South Africa (Van Niekerk, 2010; Badenhorst, 2014). Vagrant dogs (*Canis familiaris*) together with leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*) and brown hyaena (*Parahyaena brunnea*) are also accountable for some losses (De Waal, 2007; Van Niekerk 2010; Badenhorst, 2014).

Predation management by livestock farmers and wildlife ranchers are important to reduce predation risks. It is a challenge to determine losses in the wildlife ranching industry when compared to the small and large livestock industry; mainly because of differences in management practices between domesticated (livestock) and wild animals (wildlife). Livestock farmers use several methods of predation management on a daily basis (Badenhorst, 2014). Because daily activities on wildlife ranches and livestock farms differ, management practices will also differ. Predation management includes the use of non-lethal and lethal control methods. Lethal methods are assumed to be cheaper and more effective to control predators (Conover, 2001). Usually some lethal control methods are not target specific and requires continual commitment and expenses (Conover, 2001); whereas non-lethal methods usually aim at targeting the damage causing animals.

It is important to choose the correct control method that fits the predator's habit and method of preying; otherwise it may lead to increased losses, because of the difficulty in counting wildlife, the control methods used by wildlife ranchers might require more skills and it may be more expensive than for the small and large livestock industry (De Waal, 2009a).

1.2 PROBLEM STATEMENT

Predation is an old and well-known challenge globally as well as in South Africa (Knowlton, Gese & Jaeger, 1999; Shelton, 2004; Stadler, 2006; Gunter, 2008; Strauss, 2009; Van Niekerk, 2010; Badenhorst, 2014). Although losses caused by predators are usually associated with the small and large livestock industries, Cilliers (2006) stated that the wildlife ranching industry also entered the "predator-war" and that valuable antelope species such as sable (*Hippotragus niger*), roan (*Hippotragus equines*) and nyala (*Tragelaphus angasii*) are being preyed on.

As stated previously, very little is known about predation on wildlife ranches, therefore it is important for the growing wildlife ranching industry in South Africa to determine the extent and impact of predation (Badenhorst, 2014; De Waal, 2015). Determining the losses ascribed to predation are very challenging because of the difficulty in counting wildlife and their offspring and the fact that losses are not detected immediately; special skills, equipment and resources are also needed to keep count of wildlife and to distinguish whether an animal was predated or scavenged on after it died (De Waal, 2015). The considerable variation in prices of wildlife also makes it difficult to allocate a specific price to species.

The losses due to predation are not only restricted to the losses of animals; additional costs are incurred in preventing predation (Badenhorst, 2014). The animals are mostly roaming freely on wildlife ranches, thus unlike the situation on livestock farms, great challenges are created to prevent predation. For a substantial proportion of wildlife ranches the owners may only visit the properties over weekends or even less seldom; making the task of accounting for numbers even more difficult (Cilliers, 2006).

1.3 MOTIVATION FOR THE DISSERTATION

There has been a steady increase in agricultural land devoted to wildlife ranching activities (Dry, 2015), because of a large shift from sheep and cattle farming to wildlife ranching in South Africa. Two important reasons for this shift are theft and the fact that wildlife is capable of producing higher returns, more specifically in regions that are not suited for crop or livestock farming (Du Toit *et al*., 2013; ABSA, 2015; Dry, 2011; 2015).

South Africa attracts more tourists in comparison to the rest of the African continent and in 2012 more than 13 million international tourists visited South Africa (ABSA, 2015). Lehohla (2014) indicated that the tourism industry grew to an estimated ZAR 93.2 million from 2008 to 2012 and contributes 9% of the gross domestic product (GDP). An important aspect of tourism in South Africa is ecotourism and ecotourism primarily consists of services provided by wildlife ranches and national Parks (Van der Merwe & Saayman, 2002). The ecotourism industry grows between 10-15% annually and is estimated to generate billions of ZAR (ABSA, 2015). In 2014 the economic contribution of the live wildlife trade and related activities was estimated to be more than ZAR 10 billion (ABSA, 2015). The latter is an important reason to quantify the impact of predation on the wildlife ranching industry. This dissertation will contribute to the existing knowledge about the extent of predation and specifically its economic impact on the wildlife ranching industry in South Africa.

1.4 OBJECTIVES

The main goal of this dissertation was to determine the extent of losses incurred due to predation on wildlife ranches in South Africa; these losses incurred include direct and indirect costs associated with predation. This dissertation is part of a larger study that also focused on wildlife ranches in all nine provinces of South Africa. However, for the purpose of the dissertation the Limpopo province was chosen as the major research area because it comprises the largest body of Wildlife Ranching South Africa (WRSA) members and is home to a wide range of wildlife. Basic results of the other provinces are presented in **Appendices**.

It should be noted that this study was conducted among a random sample of wildlife ranchers who are members of WRSA; this membership of WRSA account for about 20% of the total number of privately owned wildlife properties in South Africa.

1.4.1 PRIMARY OBJECTIVE

The primary objective of the dissertation was to determine the economic implication of predation on the wildlife ranching industry of the Limpopo province of South Africa.

1.4.2 SECONDARY OBJECTIVES

- Estimate the direct losses of wildlife due to predation and to quantify the indirect losses of wildlife due to predation in the Limpopo province.

The dissertation aimed to determine the economic losses due to predation and the effect that it has on the wildlife ranching industry.

The direct cost is the physical losses associated with predation, but it is very difficult to attach a monetary value to an animal, especially for wildlife species; therefore the losses/ha were determined in this dissertation. The indirect costs are determined by other factors that influence predation such as the control methods, also calculated per ha.

- Investigate the factors that influence predation in the wildlife ranching industry of the Limpopo province.

This secondary objective was pursued by firstly, identifying the factors influencing the occurrence of predation, and secondly, identifying the factors that will reduce the level of predation after it has occurred (Van Niekerk, 2010; Badenhorst, 2014).

It was hypothesized that the factors that influence the small and large livestock industries are not necessarily the same as the factors that influence the wildlife ranching industry, as well as that the variables that influence the occurrence of predation is not the same as the variables that influence the level of predation. This study used a backward regression to remove any multi-colinearity problems and to increase the degrees of freedom.

- Investigate if the method of counting has a marked effect on the level of predation.

This secondary objective was pursued by doing Propensity Score Matching. The two methods mostly used by wildlife ranchers to determine wildlife numbers were compared to determine if it has a noteworthy effect on the level of predation.

1.5 DISSERTATION OUTLINE

As discussed previously, this dissertation is part of a larger study which was done in South Africa. The main focus of the dissertation is on the Limpopo province, while results of the other provinces are presented in **Appendices**.

This dissertation which was done in the Limpopo province consists of five chapters. The first part of Chapter 2 discusses the global predation issue followed by the South African wildlife ranching industry, the predation issue in South Africa and control methods used. Chapter 2 concludes with the economic implications of predation. Chapter 3 consists of the research area, sampling, the development of the questionnaires and methods and models used to analyse the data. Chapter 4 presents a discussion of the results and Chapter 5 consists of the summary and conclusion.

CHAPTER 2
Literature Review

2.1 INTRODUCTION

This chapter reviews literature reporting on the effects of predation globally as well as in South Africa, the predators associated with losses in South Africa, the environment, the management, and government regulations influencing predation, the control methods used locally and globally, the occurrence and level of predation, as well as the cost analysis.

2.2 GLOBAL PREDATION

The primary cause of human-wildlife conflict is due to competition for the same space and resources (Moberly, 2002; Shwiff & Merrell, 2004; Bothma, 2012). The only way to decrease the impact of predators is to eradicate them entirely on a regional and/or national level, but this is economically not viable and ecologically unacceptable and will cause imbalances in the ecosystem (Moberly, 2002; Shwiff & Merrell, 2004 Bothma, 2012). Predators influence the small and large livestock industry, as well as the wildlife ranching industry negatively, not only in South Africa but also globally.

In the studies by Van Niekerk (2010) and Badenhorst (2014) emphasis was placed on the global problem of predation and the influence of predators on other parts of the globe. Predators vary from brown bears (*Ursus arctos*) in Spain, wolves (*Canis lupus)* in southern Europe and Norway to jackal (*Canis aureus*) in Israel (Yom-Tov, Ashkenazi & Viner, 1995). It was observed that different predators have different effects on species and breeds (Van Niekerk, 2010) for example; Landa, Fudvangen, Swenson & Roskaft (1999) observed that different sheep breeds vary in awareness and anti-predator strategies. These different predators are responsible for major economic losses. When the indirect cost is accounted for the total cost due to predation losses will be much higher. The indirect costs are ascribed to the cost of utilising non-lethal control methods, methods assisting wildlife ranchers and lethal control methods.

Non-lethal methods and methods assisting wildlife rancheres include all control methods that do not kill predators. These methods do not provide a permanent solution to predation but can reduce the level of predation. Examples of these methods include guarding animals, cage traps, fencing and management practices (Badenhorst, 2014). Great success is associated with lethal control methods; however, these methods are mostly non-selective and non-damage causing animals are killed, except in the case when specific animals are shot. Example of lethal methods include shooting, hunting with dogs, foothold traps and poison (Arnold, 2001; Moberly, 2002; Van Deventer, 2008; De Waal, 2009b). Culling predators only temporary reduces livestock losses (Treves, 2009). A study done in north-western Alberta, United States of America, indicated that by decreasing wolf numbers from 40 to three wolves within two years resulted in an initial decrease in wolf predations on livestock; followed by a rapid increase in predation thereafter (Bjorge & Gunson, 1985). The mean number of livestock predated on increased 5-6% for cattle and 4% for sheep for each additional wolf killed (Wielgus & Peebles, 2014). These methods are used widely, for example in the United States of America guarding dogs have been used since the early 1970's and in the United Kingdom and Australia shooting is used to reduce fox numbers (Andelt, 2004).

2.3 SOUTH AFRICAN WILDLIFE RANCHING INDUSTRY

The right of ownership of wildlife granted to private landowners in 1991 laid the foundation for developing a financial viable wildlife industry (Reyneke, 2015). South Africa is probably the only African country whose wildlife numbers have increased in the past few decades. During this period 20.5 million ha of land have been converted into wildlife ranches (Dry, 2011; 2015). In South Africa 16.8% of the total agricultural land in South Africa are privately owned wildlife ranches and 6.1% are national parks and provincial reserves (Dry, 2011).

The major part of nature conservation in South Africa is taking place on privately-owned land, such as wildlife ranches (Van der Merwe, Saayman & Krugell, 2004). The private wildlife industry consists of four pillars, namely animal husbandry, hunting, wildlife tourism and game products. Each of these four pillars provides an economic contribution (Van der Merwe *et al.*, 2004; Cloete, Van der Merwe & Saayman, 2015).

The economic information of animal husbandry is limited to live wildlife auctions, which represents only a small percentage of live wildlife trade in South Africa (Cloete *et al*., 2015). The turnover in 2014, at formal wildlife auctions, was more than ZAR 1.8 billion and is expected to exceed ZAR 2 billion at the end of 2015 (Cloete *et al*., 2015); for example, at an auction held in 2014 on the Willem Pretorius Nature Reserve, 88 hunting packages were sold for ZAR 3 276 million and revenue generated over three years at this specific auction was ZAR 329 million (South African Government, 2014). By using only auction data a bias may be introduced of the estimated value of a specific wildlife species, but unfortunately other information in the wildlife sector is not widely available.

It is estimated that in 2013 the average biltong hunter spent ZAR 31 472 per year and there are approximately 200 000 such hunters in South Africa, therefore the total value of the hunting pillar is nearly ZAR 6.3 billion (Cloete *et al*., 2015). As mentioned previously wildlife tourism contributes 9% to the GDP and has not changed since 2008 (Cloete *et al*., 2015). Limited data is available on the size and economic contributions of game products, however, it is estimated that venison accounts for 42% of all fresh red meat consumed during winter (Van Der Merwe cited by Cloete *et al*., 2015).

The broader study included all nine provinces of South Africa, but this dissertation is focussing on the Limpopo province; the reason being that the Limpopo province has a large variety of wildlife and more than 45% of the current more than 1 800 members of WRSA conduct their wildlife ranching operations in the Limpopo province.

2.4 PREDATION IN SOUTH AFRICA

Human-wildlife conflict dates back to when the first settlers arrived in the Cape Colony in 1652 in South Africa (Stadler, 2006). Predators such as spotted hyaenas (*Crocuta crocuta*) and lions (*Panthera leo*) were posing large threats to livestock and the community (Stadler, 2006). High predation levels led to the introduction of the “bounty system” in 1656, where people were given monetary rewards for killing predators. The “bounty system” was the first control method used in South Africa (Stadler, 2006). In 1822 Lord Charles Somerset issued a proclamation to conserve wildlife, because harmless animals, such as aardwolf (*Proteles cristatus*) and bat-eared foxes (*Otocyon megalotis*), that plays crucial roles in the ecosystem, were killed under the “bounty system” (Stadler, 2006).

As a result of the decreasing numbers of larger predators such as the spotted hyaena and lion in certain regions of South Africa, the caracal and the black-backed jackal became much larger threats and during the Anglo Boer War (1899–1902) the predation problem increased due to carrion on the battle fields, ever since then predators have been problematic to farmers (Stadler, 2006).

In 1998 a project was initiated at the Glen Agricultural Institute in the Free State province to develop profitable and sustainable wool farming systems (Strauss, 2009). The direct losses due to predation from 2003-2007 for Merino sheep at Glen amounted to ZAR 268 650. Losses due to predation increased from ZAR 16 400 (2003) to ZAR 106 750 (2007). For Dorper sheep the total loss between 2003 and 2005 was ZAR 132 400. The minimum loss was in 2003 (ZAR 15 400) and the maximum loss was in 2005 (ZAR 31 700). Total annual financial losses (direct and indirect) for the Merino and Dorper flocks were ZAR 647 814 between 2003 and 2007; which showed that predation was a huge problem (Strauss, 2009).

Du Plessis (2013) indicated that there is a lack of scientific estimations on the economics of caracal and black-backed jackal predation as well as human predator conflict management. It was noted that wildlife ranchers and cattle farmers incur losses and that predation challenges are the primary responsibility of each farmer. Du Plessis (2013) discussed the limitations of previous studies, because these studies were all done on or confined to protected areas and were not focused on developing sustainable management strategies.

Van Niekerk (2010) studied the economic losses due to predation on small livestock and analysed management practices, which affects the occurrence and level of predation in the five largest small livestock producing provinces in South Africa. These provinces included Mpumalanga, Western Cape, Free State, Northern Cape and Eastern Cape. Small livestock younger than a month were found to be more prone to predation, while the predator mostly responsible for these losses was the black-backed jackal. Population numbers of caracal were lower in these provinces; however they were associated with the losses of older small livestock.

The Northern Cape province incurred the most losses; the direct cost was estimated to be ZAR 540 847 496; direct cost being the total losses incurred by predation. Van Niekerk (2010) also hypothesised that the variables affecting the occurrence of predation is not the same as the variables affecting the level of predation. It was thought that the variables affecting the occurrence of predation is associated with the efficiency that predation is managed with and the variables affecting the level of predation is associated with non-lethal and lethal control methods that reduce the level of predation.

The study by Badenhorst (2014) indicated that the black-backed jackal and caracal are two of the most important medium sized predators in South Africa and, together with leopard, brown hyaena and cheetah, are responsible for major losses in both the small and large livestock industries in South Africa. The main objectives of the study was to quantify the direct and indirect losses in the large livestock industry due to predation, to determine the effect of predation on large livestock specifically for the Northwest province and to investigate the underlying structure in predation prevention practices. The findings by Badenhorst (2014) that black-backed jackal, followed by caracal were responsible for the majority of the losses, supports the findings of Van Niekerk (2010). The direct cost for the North West province was estimated to be ZAR 67 776 800. The indirect cost, which is associated with the cost of using non-lethal and lethal control methods, was estimated to be ZAR 84 319 786. Badenhorst (2014) confirmed the findings of Van Niekerk (2010), namely that the variables affecting the occurrence of predation differ from those variables affecting the level of predation.

Nattrass and Conradie (2013) concluded that the killing of the black-back jackal is based on three pillars namely an opinion that killing black-back jackal is cruel, an ecological claim that is biased and protocol requesting that farmers use non-lethal control methods rather than lethal methods. For example, the National Society for the Prevention of Cruelty to Animals argue that lethal control methods are “inhumane” and that a vacuum effect may arise if damage causing animals are removed that can lead to increased losses of domesticated animals (Nattrass & Conradie, 2013).

As discussed previously, two of the most important damage causing animals in South Africa are the black-backed jackal and caracal. They are both widely distributed throughout South Africa, especially in the drier areas (Skinner & Chimimba, 2005). The remainder of the dissertation will focus only on the predators that result in the highest economic losses.

2.4.1 BLACK-BACKED JACKAL (*Canis mesomelas*)

The black-back jackal is most active in spring-during the main lambing season and at night when it is cooler. They can weigh as much as 11 kg. Adult jackal lives in pairs and has their own home ranges. Home ranges for mated pairs can be up to 1 900 ha and the average home range size of a single non-breeding jackal can be as large as 3 300 ha. Jackals mate in June or July and pups are born in August and September, the average litter consist of five pups, but litters can reach a maximum of eight pups (Beinart, 1998; Skead, 1973; Fairall, 1968). After three months the pups start to move further away from the den and from the age of six months they start to leave the den permanently (Ferguson, Nel & De Wet, 1983).

The black-backed jackal’s diet differs between location and time. They are seen as opportunistic predators that prey on almost anything that is available (Wyman, 1967; Lamprecht, 1978a,b). Their diet varies and consists among other of vegetables, berries, hares, (*Lepus* spp.) to domestic stock (Ferguson, Nel & De Wet, 1983). Usually black-backed jackal feed on small-sized prey, such as sheep and goats, but it has been observed that the black-backed jackal prey on the young of larger species, such as gazelles (Stadler, 2006). Brassine (2011) observed that black-backed jackal in the Eastern Cape province can switch their diets according to the availability of food resources.

2.4.2 CARACAL (*Caracal caracal*)

Caracal will also prey on the most available prey, even if they have to adapt their diets (Avenant & Nel, 2002). A study done, on the correlation between prey availability and prey use by caracal, found that wildlife were caught mainly in summer and autumn because caracal diets differ between seasons and areas (Avenant & Nel, 2002). Their most common prey is rodents followed by antelope, especially springbok (*Antidorcas marsupialis*), klipspringer (*Oreotragus oreotragus*), grey rhebok (*Pelea capreolus*) and mountain reedbuck (*Redunca fulvorufula*) (Avenant & Nel, 1998; Palmer & Fairall, 1988; Avenant & Nel, 2002). Caracal also prey on domestic animals that enable them to produce during winter; otherwise reproduction will usually take place in summer (Bernard & Stuart, 1987; Kralik, 1967).

The gestation period varies between 69 and 78 days and between one and five kittens are born (Zuckerman, 1953). The caracal is about 400–450 mm at the shoulder and can weigh up to 18 kg. They have a reddish colour with white fur on their stomachs. Weight and colour can vary between areas (Avenant & Nel, 1998). Caracal activity depends on weather conditions. Although they are active during day and night, they are more active if temperatures are below 20^{o}C (Stoddart, 1979; Avenant & Nel, 1998). Home ranges are much larger for males than for females.

In 2004 the Canis Caracal Programme was initiated by the African Large Predator Research Unit (ALPRU), its primary goal was to revive coordinated predator management on a national basis. (ALPRU, 2013; De Waal, 2009a,b; De Waal, 2012; Bergman, De Waal, Avenant, Bodenchuk & Nolte, 2013).

The wildlife ranching industry is unique in the sense that it includes a variety of indigenous predators, not only the black-backed jackal and caracal, but also leopard, cheetah and brown hyaena are causing damage.

2.4.3 LEOPARD (*Panthera pardus*)

Leopard is the quintessential cat specie with a very wide distribution. In Africa the leopard inhabits more than 40 countries (Nowell & Jackson, 1996). Adult leopard can weigh up to 90 kg (Stuart & Stuart, 2000). Leopard has no specific breeding season (Fairall, 1968) and young are born throughout the year. They live and hunt alone, and prey on animals as small as springhare (*Pedetes capensis*) to the size of adult springbok and larger (Bothma, 1984; Bailey, 1993; Bertram, 1999). A study by Owen-Smith and Mills (2008) revealed that leopard commonly prey on grey duiker (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris*), impala (*Aepyceros melampus*), bushbuck (*Tragelaphus scriptus*) and reedbuck (*Redunca arundinum*). Mills and Harvey (2001) recorded 92 species that leopard prey on in sub-Sahara Africa.

The majority of female leopards give birth during December and a female will only breed again if her previous litter is self-sufficient. A study by Balme, Batchelor, De Woronin Britz, Semour, Grover, Hes, MacDonald and Hunter (2012) found that cub mortality is very high, only 47% of cubs survive to become independent.

2.4.4 CHEETAH (*Acinonyx jubatus*)

Cheetahs prefer open grassland areas, because they can reach maximum speed of 100 km/h when hunting, but they will also inhabit woodlands, shrubs and bushes (Myers, 1975; Nowell & Jackson, 1996). They prefe impala, but cheetahs in different areas prey on different species (Stander, 1991). Male cheetahs can live alone or in batchelor groups of two or three, they are usually brothers. Similar to leopards, female cheetahs live alone with their cubs until they become independent. The gestation period of cheetahs is 93 days and females can reproduce again before the previous litter become independent. Reproduction can take place throughout the year, but is more frequent during the rainy season. As with leopard cub mortality is very high with, only 27.7% of cubs surviving in the den and 52.8% of the cubs up to three months of age who leave the den (Laurenson, Caro & Borner, 1992).

2.4.5 BROWN HYAENA (*Parahyaena brunnea*)

The brown hyaena's behaviour is very variable. They breed any time of year and inhabit a large variety of habitat types. Their diets vary between carrion and live prey, from as small as termites to as large as elephants (Kruuk, 1972). Cubs feed exclusively on milk for the first 5–8 months after birth and only start to feed on meat from about 12-18 months (Holekamp & Smale, 1990). The mothers seldom bring food to the den; the cubs must usually acquire it themselves (Holekamp & Smale, 1990).

As suggested by the literature reviewed above the size of prey does not matter to predators, if prey is too the large predators will just form groups to hunt; which means that even though some predators, such as the black-back jackal, are relatively small they are still able to hunt larger prey such as antelope.

The black-back jackal and caracal plays the largest role in predation in South Africa and are also the widest distributed of all the predators. Because the black-back jackal and caracal's diet differ between location and time, it is difficult to identify problem animals. The leopard and cheetah are hunters and not scavengers; however their cub mortality is very high, meaning they cannot increase their populations as fast as the black-back jackal and caracal. The litter size of the black-back jackal is also larger than the litter size of leopard or cheetah. Home ranges and vegetation types play an important role in determining the type of predator responsible for predation in a certain region.

2.5 FACTORS INFLUENCING PREDATION

Human-wildlife conflict has a long history in South Africa (Stadler, 2006; Du Plessis, 2013). As previously discussed predation problems occur globally. Other than human interference, there are a few causes of predator prey conflict, namely fire, weather and the introduction of exotic fauna and flora that plays a role (Hecht & Nickerson, 1999). These causes can be divided into factors pertaining to the environment and management and the government regulations that affect predation.

2.5.1 ENVIRONMENT

AREA

Different geographic areas play a crucial role in predation in a specific area. Taylor (1984) observed that predators catch more prey in certain areas than in others. A study on elk and wolf populations determined that elk have a higher chance of escaping from wolves in open areas; therefore the predation risk is lower in grass areas as well as in areas further away from forests and is higher in remote areas and or rough and bushy areas (Nass, Lynch & Theade, 1984; Stahl, Vandel, Ruette, Coat, Coat & Balestra, 2002; White, Garrott, Cherry, Watson, Gower, Becker & Meredith, 2009). According to Kaunda (2002) territorial black-backed jackal are more active because they have to protect their territories. Dreyer and Nel (1990) indicated that black-backed jackal utilize only specific areas within territories. The caracal's diet reflects the most abundant prey species in an area (Avenant & Nel, 1998) and they will inhabit areas that provide shelter (Shwiff & Merrell, 2004).

CLIMATE

Most predators are active during night time, when temperatures are lower; therefore the level of a predator's activity is influenced by climate. Weather patterns such as El Niño accounts for large weather and climate changes and have an effect on herbivores as well as carnivore behaviour (Philander, 1990; Hurrell, 1995; Crawford, 2000). It was observed that change in climate affects the hunting conduct and success of caracal (Philander, 1990; Hurrell, 1995; Crawford, 2000). A change in climate has a negative effect on species such as deer, which has a relatively fixed breeding time (when there is sufficient food available). Climate conditions can also have an effect on the birth weight or size of an individual. Dreyer and Nel (1990) found that black-backed jackal move to areas that will provide cover from severe temperature fluctuations. Avenant and Nel (1998) indicated that caracal are more active during night-time when temperatures are cooler.

FOOD AVAILABILITY

Bromley and Gese (2001) found that coyotes change their predatory habits in the presence of pups and the litter size of coyotes increase as the availability of food increases (Link, 2004). Predators are able to change their diets according to food availability (Avenant & Nel, 2002). It was observed that black-back jackal could consume different types of food each season. Kamler, Klare and Macdonald (2012) found that there were large differences in the black-backed jackal's diet between autumn and spring and autumn and winter. Black-backed jackal will increase their territorial area if food availability is scarce. Caracal, on the other hand, can switch their diets as prey abundance decreases; they will then utilize prey as they move between areas.

2.5.2 MANAGEMENT

McAdoo and Glimp (2000) stated that a proper management plan is just as important as a predator control program and together with Shivik (2004) illustrated that good management practices can reduce the level of predation. Management practices will differ between predators and will have a marked effect on the impact of predation on wildlife. Since the earliest times there has been bickering about which management practices to use, the largest debate is usually when predators are entirely removed (Knowlton, Gese & Jaeger, 1999). Management practices should include legal, social and biological aspects (Knowlton *et al.,* 1999). The main objective of predation management is to reduce losses incurred due to predators (Shwiff & Bodenchuk, 2004). Some proponents propose that management programs for livestock can also benefit wildlife.

Another debate regarding predation management is whether the benefits of a predation management program exceed the costs (Bodenchuk, Mason & Pitt, 2000). To estimate the benefits of a predation management program it is necessary to determine losses without a management program (Shwiff & Bodenchuk, 2004). The cost of predation management includes the value of direct management activities and cost of services while the indirect cost includes investments for additional production efforts (*Bodenchuk et al.,* 2000). Bodenchuk *et al.* (2000) reported that predation on sheep is much higher in the absence of a management program and in Zimbabwe 43% of livestock losses were due to bad management practices; indicating that farmers can prevent losses by being more vigilant and to keep livestock from straying (Rasmussen, 1999; Graham, Beckerman & Thirgood, 2005).

2.5.3 GOVERNMENT REGULATIONS

Regulation of damage causing animals in Limpopo is stated under the Limpopo Environmental Management Act No. 7 of 2003 (Greyling, 2006). This legislation states that the landowner may hunt damage causing animals when they become a problem (Greyling, 2006). However, a non-owner requires a permit together with permission from the landowner in writing (Greyling, 2006). Poison is only allowed under the control of delegated authority and the use of dogs is only allowed under direct supervision of an Environmental

Compliance Officer (Greyling, 2006). There are no restrictions on the amount of black-backed jackal and caracal that are culled in a year; they can also be hunted from 1 January to 31 December (Proclamation by the Member of the Executive Council for the Department of Economic Development and Environmental Affairs, 2011). Regulation between provinces differ.

There is a lack of involvement by governments in especially developing countries (Oli, Taylor & Rogers, 1994). In South Africa farmers need to address the problem themselves and the easiest solution for them seems to be killing; farmers do not get compensated for damage done by predators (Mishra, 1997; Breitenmoser, Breitenmoser-Würsten, Okarma, Kaphegyi, Kaphegyi-Wallman & Müller, 1998).

In South Africa the situation of land reform is becoming an increasing problem. In future problems could exist such as farmers/wildlife ranchers may only be allowed to have 12 000 ha of land, meaning they must become more profitable on smaller area (ha). With wildlife, more expensive animals can be kept on a smaller piece of land; this will increase demand in the future for more expensive species (ABSA, 2015).

For this dissertation it was important to determine where the wildlife ranches are located, because different geographical and topographical areas have different predators and the extent of predation will also vary between different areas. The vegetation type also plays a crucial role because antelope has a higher chance of escaping from predators in open grassland areas (less predation). Climate changes can disrupt the breeding season of wildlife species: they usually calve in the wet season, when food is abundant, but with changing climate the rain season changes and antelope will calve when less food is available if they do not adapt (Sekulic, 1978). This means antelope will be weaker and preyed on much easier. From a management perspective it is necessary for wildlife ranchers to control predation on their wildlife ranches, whether they use non-lethal or lethal methods. Wildlife ranchers need to find the most appropriate methods that will work on their specific wildlife ranch.

2.6 SOUTH AFRICAN CONTROL METHODS

The Free State Problem Animal Hunting Club, better known as "Oranjejag" was established in 1965 and mandated by the Free State Problem Animal Control Ordinance to remove (kill) problem animals; at its peak "Oranjejag" employed 20 hunters, operating with 1 000 hunting dogs (Ferreira, 1988). The idea of using hunters and trappers originated from the United States, where they were used to kill coyotes (Beinart, 1998). Membership was compulsory for South African livestock farmers up until 1970 (Du Plessis, 2013) and subsidized by the government. Membership numbers decreased from 15 904 (1970) to 5 200 (1973) after membership became optional (Du Plessis, 2013). Hunters of "Oranjejag" killed approximately 87 570 animals in the Free State province alone between 1966 and 1993. In 1993 "Oranjejag" was discontinued and the primary responsibility of predation management was turned over to private landowners in the mid 90's (Du Plessis, 2013; Pickover, 2005).

In 2009 livestock farmers and wildlife ranchers established the Forum for Damage Causing Animals; the name was later changed to the Predation Management Forum of South Africa (PMF) (De Waal, 2009b). The PMF comprised representation by the National Wool Growers' Association (NWGA) of South Africa, the Red Meat Producers Organisation (RPO), the South African Mohair Growers' Association (SAMGA) and Wildlife Ranching South Africa (De Waal, 2009b). The vision of the PMF is to empower wildlife ranchers and farmers to effectively manage predators, to protect the biodiversity and improve the knowledge of consumers so that they can make informed decisions. The PMF addresses the old challenges of predation to ensure jobs, food security and biodiversity (Bergman *et al.,* 2013).

Recently Du Plessis, Avenant and De Waal (2015) alluded to the paucity of published scientific information regarding the black-back jackal and caracal. A strong case was made to develop a focused research programme in South Africa to fill the critical gaps in current knowledge.

Predator control includes fencing, hunting and poison. The "skaapwagter" is a non-lethal control method used by farmers in South Africa. It is a solar powered device that generates a range of ultra-high frequencies that is extremely irritating to predators. Farmers using the "skaapwagter" reported decreases in lamb losses of up to 90% (Erasmus, 2012).

2.6.1 NON-LETHAL AND LETHAL CONTROL METHODS

Non-lethal control methods and methods assisting wildlife ranchers or farmers are all the control methods that do not kill predators, these methods are usually not a permanent solution to predation problems; it can only reduce the level of predation. Lethal control are non-selective and can also kill non-damage causing animals. Table 2.1 highlight some of the non-lethal and lethal control methods.

Table 2.1 Types of control methods

Non-lethal control methods	Lethal control methods
King collars	Hunting
Fencing	Poison
Guarding animals	Trapping
	Coyote getters
	Hunting with dogs

Wire mesh is widely used in South Africa as a method to control black-backed jackal. Jackal-proof fences help to restrict jackal movement (Heard & Stephenson, 1987). An alternative method of electric fences can be used successfully to prevent predators. Before these fences were erected predators could move freely between farms and the only way of safeguarding livestock was by constructing kraals. Fences can be a very effective control method when used in combination with foxhounds (Heard & Stephenson, 1987).

Two large problems exists with jackal-proof fences, firstly it is costly and secondly animals such as porcupines, warthogs and bush pigs burrow underneath the fences which makes it inefficient (Heard & Stephenson, 1987). This led to coordinated hunting clubs (Stadler, 2006). Poison was used in conjunction with hunters. In 1889 The Cape government subsidised the use of strychnine. Poisoning clubs were introduced and the Department of Agriculture became a key campaign driver.

In the Northwest province of South Africa (Thorn, Green, Dalerum, Bateman, & Scott, 2012) 66.67% of farmers confirmed that they use lethal control methods, while 33% of the farmers shot predators, 20% used poison, 14% hunted at night and shot predators by luring them with vocalised animal sound, 14% hunted with dogs and 14% used cage traps and then shot the predators. The remainder of the farmers used non-lethal methods which are selective in the animals that are killed (Thorn *et al.*, 2012).

As seen above, in the control methods of the world and South Africa, one can distinguish between non-lethal and lethal methods. Non-lethal methods are selective in the animals that it kills and lethal methods are unselective in terms of the animals that it kills. Lethal methods also include snares and poisoning. Greentree, Saunders, Mcleod and Hone (2000) indicated that poisoning could reduce predation by 6.5%. Avenant and Du Plesssis (2008) discussed the implications of increasing livestock losses when using lethal control methods.

Predation management is a controversial topic because management can include the killing of predators, therefore the use of non-lethal methods is encouraged. De Waal (2009) stated that non-lethal methods would reduce the level of predation, but not the occurrence. Van Niekerk (2010) and Badenhorst (2014) also observed a difference between the occurrence of predation and the level of predation. Van Niekerk (2010) found that using a combination of non-lethal methods was significant, it will decrease the level of predation and also the occurrence of predation. Van Niekerk (2010) also indicated that an increase in management would lead to a decrease in predation.

Badenhorst (2014) recommended that it is important to use management practices in the correct manner. Badenhorst (2014) also indicated that hunting with dogs and the use of foothold traps are not the best control methods if predation is not incurred; government and producers organisations assistance is also necessary.

2.7 OCCURRENCE VERSUS LEVEL OF PREDATION

This dissertation focussed on whether or not predation occurs and if it does occur at what level does it occur. The occurrence of predation is related to management practices, factors that can avoid predation. The level of predation relates to those factors that decrease predation, in other words non-lethal and lethal control methods.

Tobit or Probit regression models are used to model variables affecting the occurrence of predation, while variables affecting the level of predation are modelled using the Truncated regression model. It is expected that nearly all lethal methods will be significant in the Truncated model, because they will not stop predation, they will only decrease the level of predation; whereas non-lethal methods will decrease the level of predation but will not automatically have an influence on the occurrence of predation.

Several studies (Van Niekerk, 2010; Badenhorst, 2014) have been done on the control methods and the cost of damages done to the small and large livestock industry, but not a lot is known about the cost and losses due to predation in the wildlife ranching industry in South Africa. The value of the losses due to predation and various other factors, such as diseases, play a crucial role in correctly evaluating predation in the wildlife ranching industry in South Africa.

2.8 COST ANALYSIS

The total cost can be divided into direct and indirect cost. The direct cost is associated with the losses regarding predation and the indirect cost is associated with cost of management and control.

2.8.1 DIRECT COST

Determining the losses and cost due to predation in the small and large livestock industry is much easier than in the wildlife ranching industry because they can be managed, controlled and counted with ease. Wildlife numbers can be determined through physical counting, predicting the Rand value, estimating and the amount of wildlife available to hunt. When determining the total cost of predation it is important to also include the resources used to control or prevent losses, labour, damage done to fences, injuries incurred, losses in genetics and abortions due to stress; it is much more than just the physical killing of the specific wildlife species.

There are a few methods to evaluate the direct cost of losses due to predation. Moberly (2002) argued that direct losses could be estimated by determining the value of the animal at the point of loss, the “finished product”, or the output loss. The values allocated to the different species in this dissertation is the same, regardless of whether the animal is used for breeding purposes, values for males and females differ, trophy or biltong hunting. However, determining the losses in the wildlife ranching industry is very difficult due to the variability in the different wildlife species’ prices. What makes it even more difficult is, if that wildlife species is killed when it was not yet at the point of sale. The total cost of losses due to predation is determined as:

$C = L + E$

Where:

C = Total cost

L = Loss of the animal

E = Direct and indirect expenditure cost and control expenditure

Mclnerney, Howe and Scheepers (1992) and Otte and Chilanda (2001) determine the total cost by adding the loss of the animal with the cost of control and expenditure cost.

A second method is to use the market value of the animal at the point of death. For example, if a weaned calf was predated on, the weaning price of feedlots would be used and if the animal was in production it will take the value in accordance to the market price.

It is extremely difficult to determine the direct cost in the wildlife ranching industry because there is such a variety of species as well as different values allocated to wildlife. If a value is allocated to the total losses it might lead to an over or under estimation of losses, for example not all impala are for hunting purposes, some are used for breeding.

2.8.2 INDIRECT COST

The indirect cost includes all the methods used to prevent and control predation, as well as replacement animals (Van Niekerk 2010; Badenhorst, 2014). The effectiveness of the methods and the type of operations on the wildlife ranch/farm and the wildlife rancher/farmer's tolerance for losses can make it difficult to determine the indirect cost.

2.8.3 COST-EFFECTIVENESS OF CONTROL METHODS

There are a few analyses that can be used to decide which control method are the cheapest but most efficient.

Firstly, the benefit-cost analysis of predation management involves estimating the monetary value of the benefits of wildlife saved by the reduced predation versus the amount spend to remove predators (Moberly, 2002). Contingent valuation method can be used to test the public's willingness to pay. A benefit cost analysis should then use these values in an economic analysis (Taylor, Rashford, Coupal, & Foulke, 2009). A benefit-cost analysis is very simple and easy to use and can be used for a variety of scenarios. It is important that the estimates for the calculations are correct (O'Farrell, 2015). This analysis does not imply that the method is efficient, only that the benefits exceed the costs.

Secondly, the cost-effectiveness analysis determines the most cost efficient method of achieving the goal (Taylor *et al.*, 2009). The analysis can be used for predator control to determine the least cost combination of predator control methods to decrease predation rates (Taylor *et al.*, 2009). Cost-effectiveness analysis also does not mean that the method is the most efficient; other methods can be more beneficial at the same cost. The cost-effectiveness analysis is usually less costly, time consuming and disputed (Taylor *et al.*, 2009).

Thirdly, the cost-utility analysis can be used for methods with clear objectives (Taylor *et al.,* 2009). Cost-utility analysis finds correlations between different methods and measures the outcome in utility (Taylor *et al.,* 2009). The live weights of livestock saved are the type of information needed to do a cost-utility analysis, not only the amount of predators eliminated (Taylor *et al.,* 2009).

Fourthly, the budget-analysis just records the cost associated with the method, without any information about the efficiency (Taylor *et al.*, 2009). The money spent varies between the types of control methods used. For example: when guarding dogs are used, the purchase price of the breed, replacement costs of dogs that died, health care, feed and transport fees are all factors that need to be accounted for; while the primary benefit is the value of animals (wildlife) saved through using the specific control method (Green, Woodruff & Tueller, 1984).

2.9 SUMMARY OF RESEARCH

Predation is an age-old problem; major losses are experienced in the small and large livestock industry globally, as well as in South Africa. The South African wildlife ranching industry is a growing industry with a lot of potential. The demand for expensive species is said to increase while ecotourism is also on the rise. Trophy hunting will still receive higher prices even if prices of wildlife meat would decrease; due to the demand of international hunters. The extent of predation in the wildlife ranching industry is not yet clear; therefore a study like this is needed to determine losses.

It is important to determine which predator species are responsible for the losses, so that the correct control methods (non-lethal and lethal) can be used to control predation, bearing in mind that certain predators, are by law, not allowed to be killed. In South Africa the black-back jackal and caracal causes the most damage in the livestock industry; therefore these two species receive the most attention, although the effect of the leopard, cheetah and brown hyaena are also considered. There are certain factors that influences predation such as topography, climate, food availability, management and government regulations.

Various economic methods can be used to determine the economic implication of predation globally. Previous studies by Van Niekerk (2010) and Badenhorst (2014) studied the economic methods of estimating the cost of predation and provided a basis on which both direct and indirect cost can be determined as well as various cost analysis that can be used to decide what control method will be the most efficient. Methods previously used can serve as a basic for calculations but the data might not be of such a nature that these methods can be used. For example, data may only be appropriate to calculate the costs and the factors that affect predation but may be inconclusive to determine the benefit-cost analysis. Furthermore, the task of determining the extent of the losses of predation is not going to be an easy task due to the varying wildlife prices.

The literature review gave rise to an all inclusive questionnaire that was used to conduct a survey among wildlife ranchers. The questions included in the questionnaire will be discussed in Chapter 3.

CHAPTER 3
Methodology

3.1 INTRODUCTION

Chapter 3 provides an overview of the research area, sampling methodology and development of a structured questionnaire. Procedures to calculate direct and indirect cost of predation in the wildlife ranching sector was developed and used to obtain relevant information and analyse the information in detail for the Limpopo Province. The Tobit, Probit and Truncated models have been used to investigate factors influencing the occurrence and level of predation, as well as, Propensity Score Matching to determine the best method of counting wildlife.

3.2 RESEARCH AREA

There are more than 10 000 privately owned wildlife ranches in South Africa (Dry, 2011; 2015) comprising about 20.5 million ha (Du Toit *et al*., 2013). Van der Merwe and Saayman (2003) cited information from literature showing that in 2002 a total of 5 061 game farms with a surface area of 10 364 154 ha were classified as exempted. According to Dry (2011) there were 7 500 exempted wildlife ranches in 2011 and another 3 000 were classified as wildlife ranches with mixed operations. In this context "exempted" means that these wildlife ranches have permission to hunt within their boundaries (Van der Merwe & Saayman, 2003) because they have been fenced according to the regulations of the nature conservation authorities (Van der Merwe *et al*., 2004).

The conversion rate from livestock farming to wildlife ranching is 2-2.5% per year; meaning that farmers who previously farmed with cattle, sheep or goats are converting their farms to wildlife ranches (South African Year Book 2013/2014). South Africa is exporting between 600 and 2 000 tons of wildlife meat per year, contributing more than ZAR 8 billion to the South African economy (South African Year Book 2013/2014). There was an increase of live wildlife sales the last few years and in 2013 the total turnover of wildlife was estimated at ZAR 1 029 billion when 23 963 animals were sold (Bezuidenhout, 2014).

Limpopo is the most northerly province in South Africa and covers an area of 12.46 million ha of which 37.7% is suitable for arable farming, 50.1% for grazing and 12.2% for wildlife (Mmbengeni & Mokoko, 2002). According to the 2011 census; 5 404 868 people live in Limpopo (Stats SA, 2011). Limpopo is also the province with the largest rural population in South Africa (Mmbengeni & Mokoko, 2002). The Limpopo province (Figure 3.1) borders the Mpumalanga, Gauteng and the North West provinces, as well as Botswana, Mozambique and Zimbabwe (Mmbengeni & Mokoko, 2002).

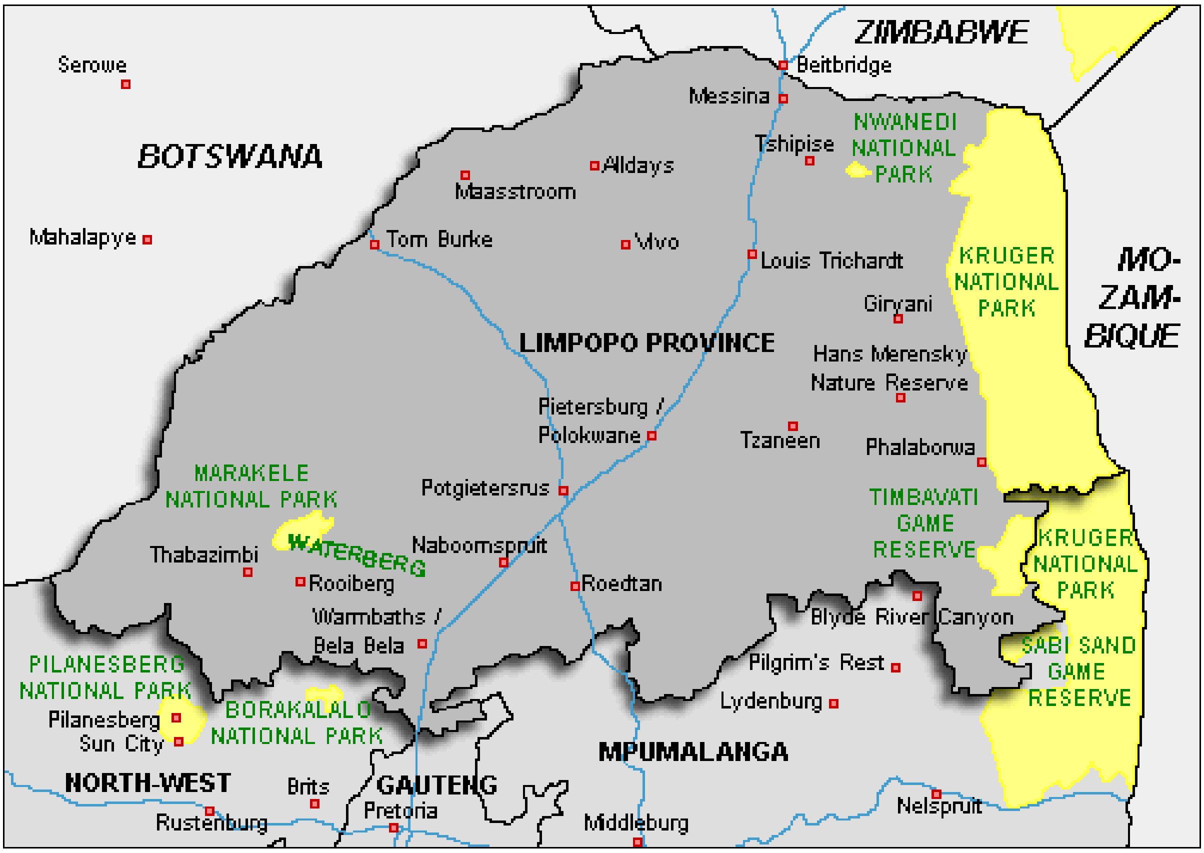

Figure 3.1 Limpopo Province of South Africa

Source: www.sacarrental.com

The Kruger National Park is situated in the Limpopo and Mpumalanga Provinces, which also have 54 provincial reserves and the largest number of private wildlife ranches. The Limpopo province is also endowed with indigenous forests, bush veld, wilderness, mountains and farmland. The average rainfall for the province is 691 mm annually and the majority of rain falls between November and March (Mmbengeni & Mokoko, 2002). The northern and eastern regions are subtropical and there is usually no frost in winter. Various fruit crops are grown in Limpopo such as; litchis, paw-paws, mangoes, pineapples, avocados and bananas as well as nuts. Limpopo also has forest plantations that produce timber and wood for furniture manufacturing. Other livestock sectors include cattle and sheep farming. It is estimated that Limpopo have 2 644 cattle farmers with 411 080 head of cattle, making a 5% contribution to the South African large livestock industry (NDA, 2012).

3.3 SAMPLING

Olken and Rotem (1986) suggested a sample of the population should be used to save time and money, so that the time and money can be allocated to better quality research. Sample sizes are widely addressed in the literature and according to De Vos, Strydom, Fouche and Delport (2002), a sample can be defined as a method of collecting a portion of a population that includes all probabilities of *n*. It is generally noted that the larger the population size the smaller the percentage of the population sample needs to be (De Vos *et al*., 2002). Certain factors such as accuracy, heterogeneity of the population, number of variables, availability of resources and the type of sample plays a role (Geweke & Singleton, 1980).

Commonly used methods of survey include: direct observations, personal interviews, surveying records, mailed questionnaires and telephone interviews (Bluman, 2004). There are four basic methods of sampling, namely: Random Sampling, Systematic Sampling, Stratified Sampling and Cluster Sampling (Hashim, 2010).

Random sampling is when a computer program or random-number table is used to choose samples; it is a purely random process (Neuman, 2004). Random sampling is used to estimate certain important parameters or hypothesis testing for statistical analysis of data (Olken & Rotem, 1986). Systematic Sampling is the same as simple random sampling except with a shortcut for random selection, through intervals (Neuman, 2004). Stratified Sampling divides the population into categories and chooses samples from each category (Neuman, 2004). Cluster Sampling is where the entire population are divided into clusters (groups) and a random sample is taken from the cluster (Neuman, 2004).

Quantitative methods are used to make assumptions about larger data sets (Holton & Burnett, 1997). Two errors can occur: the alpha and beta error. The alpha error is where a difference is found that does not exist and beta error is when an error that does exist is not found (Peers, 1996). Choosing the variables that must be incorporated into the formula is very important. The alpha level is the level of risk that is taken by the researcher that the true margin of error exceeds the acceptable margin of error. The alpha level is integrated into the formula by using the t-value for the alpha level chosen (Barlett, Kotrlik & Higgins, 2001). The t-value becomes more important as the population size decrease (Barlett *et al*., 2001). An alpha level of 0.05 is usually used and an alpha level of 0.01 when marginal relationships are identified; also when the decisions made can have financial implications or harm people (Barlett *et al*., 2001). A margin error of 5% is acceptable for categorical data and 3% for continuous data (Krejcie & Morgan, 1970).

According to Seaberg (1988) a 10% sample would be adequate to control sample errors. Stoker (1985, cited by De Vos *et al.*, 2002) suggested that for a population size of 1 000 only 140 respondents is necessary, which is a 14% sample. Although there are more than 10 000 wildlife ranches in South Africa (Dry, 2015), this dissertation focused only on members of Wildlife Ranching South Africa (WRSA). The number and distribution of WRSA members per province are shown in Table 3.1. A target group of 201 wildlife ranchers were selected for the Limpopo province from the WRSA membership and contacted by telephone to participate in the survey. The wildlife ranchers residing in the Gauteng province all have wildlife ranches in the Limpopo province.

A total of 201 (23.29%) respondents were randomly contacted in the Limpopo province and the questionnaires completed by telephone interview; this number represented more than the 10% suggested by Seaberg (1988) and the minimum number suggested by Stoker (1985).

Table 3.1 Number and distribution of members of Wildlife Ranching South Africa and the adjusted proportion of respondents selected finally for the survey

Province	Total number of WRSA members	Percentage of WRSA members	Number of WRSA members sampled	Percentage of WRSA members sampled in each province
Gauteng	147	7.78	0	0
Kwa-Zulu Natal	69	3.65	3	4.35
Limpopo	863	45.64	201	23.29
Mpumalanga	76	4.02	4	5.26
Northern Cape	119	6.29	8	6.72
North West	264	13.96	61	23.11
Eastern Cape	137	7.24	10	7.3
Free State	157	8.3	64	40.76
Western Cape	59	3.12	2	3.39
Total	1891		353	

Source: Wildlife Ranching South Africa

However, it was deemed prudent to include the data for at least two other provinces to be subjected to analysis with specific models (later described in 3.5 Procedure). Therefore, it was realised that a minimum of about 55 respondents were required for each of the two other provinces to run the models properly. The North West and Free State provinces had the second and third highest number of WRSA members; therefore it was decided to increase the number of respondents for these two provinces to be included as shown by the adjusted numbers in Table 3.1. For comparisons, the descriptive statistics for the remaining provinces are included in the **Appendices**.

3.4 QUESTIONNAIRE AND DATA COLLECTION

A structured questionnaire was used to collect primary data by telephone from respondents. The questionnaire was constructed based on a comparable questionnaire which was developed for a previous survey among cattle farmers by Badenhorst (2014).

Initially it was decided to contact the broadest possible range of wildlife ranchers and the WRSA offered to distribute the questionnaire by e-mail to its membership who could be contacted in this way. The WRSA secretariat mailed the questionnaire twice by e-mail to all

WRSA members. However, the response was very poor; only 0.8% of the wildlife ranchers responded to the request by e-mail and the questionnaires that were returned were also completed poorly. In an effort to get the important study underway and conduct the survey by the University of the Free State (UFS), the WRSA executive was requested to authorise the UFS to contact their members on a confidential basis by telephone to have the questionnaires completed.

Badenhorst (2014) divided the questions into four broad categories, namely: socio-economic factors, managerial factors, non-lethal methods, and lethal methods of controlling predation. In this dissertation the questions were also grouped accordingly in categories, namely: wildlife rancher and ranchers' perception, managerial factors, non-lethal methods and methods assisting wildlife ranchers and lethal methods of predation control.

The questionnaire included a wide range of questions, which came to light in the literature review, namely general questions such as the name, age and gender of the wildlife rancher, size of the wildlife ranch, topography, the presence of livestock on the wildlife ranch, the economically important wildlife species and how predation is measured on the wildlife ranch, followed by more detailed and specific questions about predation and predation control methods.

Wildlife ranchers were provided with a few options to choose on how they determine the wildlife losses, namely: physical counting the animals by means of aerial counting, drive census and known groups, Rand value (ZAR) based on the sales of live animal, trophy hunting and hunting for biltong, estimating the animal numbers compared to the numbers for the previous year and the number of wildlife available to hunt.

Control methods included were divided into non-lethal methods and methods assisting wildlife ranchers and lethal methods. Wildlife ranchers were asked to indicate if they make use of predation control methods and, if so, what type of methods they use on their wildlife ranches to control predation. Non-lethal control methods include cage traps, providing feed to predators, strobe lights, radios and cameras. The lethal methods and methods assisting wildlife ranchers include foothold traps, guarding dogs, hunting and poison.

The wildlife ranching industry is much more diverse than the small and large livestock industries and prices vary greatly among species therefore, this study grouped the antelope species into three categories, namely large species, small species and scarce species/colour variants. As a guideline the antelope species was classified as large if the males are referred to as bulls and females as cows, and antelope species was classified as small if the males are referred to as rams and females as ewes. The five species with the largest number of predation in every category were chosen to represent each group.

3.5 PROCEDURE

In this dissertation predation losses were quantified to create a fiscal economic value for predation in the Limpopo province of South Africa. A regression analysis was used to identify the factors affecting predation on wildlife ranches in the Limpopo province.

3.5.1 QUANTIFYING PREDATION LOSSES

The primary objective of the dissertation was to determine the economic impact of predation on the wildlife ranching industry, more specifically the dissertation report on wildlife predation in the Limpopo province. This was done by quantifying the direct losses and estimating the indirect losses of antelope due to predation and by investigating the factors that influence predation in the wildlife ranching industry.

Van Niekerk (2010) determined the losses by multiplying the number of animals (sheep and goats) lost with the relevant market prices. Badenhorst (2014) also determined the direct cost of predation in the large livestock industry by calculating the total number of cattle that died and dividing it with the total number of cattle. This cannot be done for the wildlife industry, because wildlife ranchers seldom know the exact numbers of wildlife on their wildlife ranches. It is also important to note that there is a difference between assessing animal numbers in open areas (estimations) and camps (known numbers).

Van Niekerk (2010) and Badenhorst (2014) determined values at point of sale for animals based on values of the National Livestock Theft Forum, but such values do not exist for the wildlife industry. As discussed later in detail, values for the different species are attached in the **Appendix H** for wildlife ranchers to calculate their own losses in terms of ZAR values. The values in **Appendix H** are provided as baseline for average prices to be used by wildlife ranchers. Prices in the different wildlife sectors vary, for example prices of breeding animals are higher than for biltong hunting.

With reference to the two problems discussed above, it is very difficult to determine the direct cost of predation in the wildlife ranching industry compared to what was possible in the case of the small and large livestock industries. Therefore, quantification of the direct cost of predation will lead to an over or underestimation. By determining the number of antelope that was lost due to predation in the dissertation, the wildlife rancher can make his own calculations regarding the direct cost of predation on his wildlife ranch. The total number of predation indicated by wildlife ranchers in the Limpopo province for each species was divided by the number of wildlife ranchers that owned that specific species to calculate the average value of predation for wildlife ranchers owning the same species in this dissertation. The average hectare on which each species is ranched with was also calculated. The direct cost can be calculated by using the values given in **Appendix H**.

The indirect cost of predation refers to all the costs that relate to the prevention of predation, for example: hunters, poison, cameras, cage traps, and game rangers. This cost can also be a once off expenditure for instance such as fences, but aftercare and maintenance are always necessary. Expenses due to prevention are not a guarantee that wildlife ranchers will not incur losses. Adding all the indirect cost and dividing it by the total number of hectares of the wildlife ranchers in the dissertation yielded an estimate of the indirect cost; this is then represented as ZAR value/ha. This value will give wildlife ranchers a baseline to calculate their own indirect cost due to predation. The value arrived at can then be compared to others studies, for example Badenhorst (2014), where the objective was also to calculate the losses due to predation in the large livestock industry, to determine how the two industries differ.

3.5.2 IDENTIFYING FACTORS AFFECTING PREDATION

The secondary objective of the dissertation was to determine the factors that have an influence on predation on wildlife ranches in the Limpopo province, South Africa. Van Niekerk (2010) and Badenhorst (2014) observed that the factors that affect the occurrence of predation differs from the factors that affect the level of predation, therefore it was also hypothesised in this dissertation that the variables affecting the occurrence of predation differs from the variables affecting the level of predation. The same principles followed for small and large livestock industries, can be applied for the wildlife industry. Firstly, the factors that affect whether predation occurs or not will be determined and, secondly, if predation occurs on wildlife ranches, the factors that determine the level of predation is determined. It is important to include all the observations, even if no predation was incurred.

3.5.2.1 OCCURRENCE AND LEVEL OF PREDATION

A Tobit model was used to identify factors that have an influence on the occurrence of predation. Whether or not predation occurs was measured by dummy variables (1 = predation exist; 0 = predation do not exist). There are certain problems regarding the Tobit model, such as the fact that the model is very restrictive (Lin & Schmidt, 1982). Any variable that increases the probability of a non-zero value must also increase the mean of the positive values; this is not always reasonable (Lin & Schmidt, 1982). Therefore any variable that increases the occurrence of predation will have an increasing effect on the level of predation. Another problem with the Tobit is that it links the shape of the distribution and the probability of the positive observations (Lin & Schmidt, 1982).

The Cragg's model, which is a double hurdle model, can be used as an alternative to the Tobit model. This model assumes two sets of parameters; one set determines the probability that predation will occur and the second set determines the level of predation.

The Cragg's model consists of a Probit model and a Truncated regression model. The Probit model was used to determine whether predation will occur or not (the probability that predation will occur). The Probit model, as represented by Katchova and Miranda (2004) are as follows:

$$\mathrm{P}(\text{ß}\mathrm{i} = 0) = \Phi\left(-\frac{\beta\alpha^{'}Xi}{\sigma}\right)$$

Where:

P = is the probability

ßi = quantity of wildlife predation

Φ (.) = the standard normal probability density function

βα = a vector of coefficients

Xi = variable or an S×1 vector of personal and ranch characteristics for rancher *i*

σ = variance

A backward linear regression was performed to eliminate insignificant variables from the regression.

The Truncated model was used to determine the level of predation. The dependent variable for the level of predation is a continuous variable in the Truncated regression model that measures the percentage less antelope in 2014 compared to 2013. The Truncated model, as represented by Katchova and Miranda (2004) are as follows:

$$f(\alpha i|\alpha i > 0) = \frac{f(\alpha i)}{P(\alpha i > 0)} = \frac{\frac{1}{\sigma}\,\phi(\frac{\alpha i\text{-}\beta^{'}\alpha Xi}{\sigma})}{\Phi(\frac{\beta\alpha^{'}Xi}{\sigma})}$$

Where:

f(.) = the probability density function

P = the probability

αi = the density (quantity) for the positive values

Φ(.) = standard normal probability density function

βα = a vector of coefficients

Xi = a variable or a S×1 vector of personal and ranch characteristics for rancher *i.*

σ = variance

The Cragg's test is based on a comparison between the likelihood ratios (Lin and Schmidt, 1984). The log-likelihood in Cragg's model is a sum of the log-likelihood of the Probit model and the log-likelihood of the Truncated regression model. The Cragg's test statistic, calculated from the estimated log-likelihoods for the functions, is represented by Katchove and Miranda (2004) as:

$\lambda = -2\ [\ln LTobit - (\ln LProbit + \ln LTruncated\ regression)]$

Where:

λ = likelihood ratio statistic

$LTobit$ = likelihood for the Tobit model

$LProbit$ = likelihood for the Probit model

$LTruncated\ regression$ = likelihood for the Truncated model

The estimated test statistic is compared to a critical value (χ^2 distribution table) to determine if the factors that determine the probability of occurrence and the level of predation are the same. If the Cragg's test statistic is greater than the critical value (significant probability [ρ] value) the variables affecting predation in the wildlife ranching industry will differ significantly from the factors affecting the level of predation in the wildlife ranching industry, as hypothesized. In other words, the double hurdle model is the preferred method to investigate wildlife predation. If the probability is insignificant, the variables affecting the occurrence and level of predation will be the same and the specifications of the Tobit model would be sufficient.

Data were analysed for all three groups of antelope (large, small and scarce/colour variant antelope) for the occurrence as well as for the level of predation. Names of different mammalian species used in this study **(Appendix H)** are in accordance with those listed by Bronner, Hoffmann, Taylor, Chimimba, Best, Matthee & Robinson (2003). The Tobit, Double Hurdle model and the Cragg's test statistic were estimated using NLOGIT 4.0, while the backward regression was performed using IBM SPSS Statistics 23.

3.5.3 PROPENSITY SCORE MATCHING

To determine if physical counting is more appropriate to use by ranchers than estimating, propensity score matching was done to test if the variables resulted in a significant difference in the level of predation. Propensity score matching is a multivariate approach that allows the researcher to match individuals in a treatment group to others that did not receive treatment but have comparable characteristics (Rosenbaum & Rubin, 1983):

$p(X) \equiv \Pr(D = 1|X) = E(D|X)$

Where:

$D = \{0,1\}$ = indicator of exposure to treatment

$X =$ multi-dimensional vector of pre-treatment characteristics

The propensity score model is a Probit/Logit model with D as the dependent variable and X as independent variables (Katchova, 2013). Observations need to be assigned into two groups, firstly, the treated group that received treatment and secondly, the control group that did not receive treatment (Katchova, 2013). Treatment D is a binary variable that determines if the observation has the treatment or not. The treated observations take a value of 1 (one) and the control observations take a value of 0 (zero). In this dissertation the treated observations are physical counting and the control observations are estimating.

If the treatment's exposure is random within cells defined by X, it will also be random within cells defined by values of one-dimensional variable $p(X)$ (Becker & Ichino, 2002). Therefore, if population units are implied by $\boldsymbol{i}$, the propensity score $p(Xi)$ is known, then the Average effect of Treatment on the Treated (ATT) can be estimated (Becker & Ichino, 2002). More than just an estimation of the propensity score is needed to estimate the ATT, therefore observations from treated and control groups need to be matched based on their propensity scores (Becker & Ichino, 2002; Katchova, 2013). Matching methods include kernel, nearest neighbour, radius and stratification matching (Becker & Ichino, 2002; Katchova, 2013).

KERNEL MATCHING

Kernel matching are non-parametric matching estimators that use weighted averages of all individuals in the control group to construct the counterfactual outcome. Each treated unit is matched with several control observations, with weights inversely proportional to the distance between treated and control units. One advantage of this approach is the lower variance that is achieved due to the use of more information. A large disadvantage of using this method is that some observations that are used are bad matches (Katchova, 2013).

NEAREST NEIGHBOUR

This method is the most straightforward matching estimator. The nearest neighbour method consists of taking the treated unit and matching it with the closest propensity score (Becker & Ichino, 2002). Several variants are proposed, with replacement and without replacement. With replacement means an untreated individual can be used more than once as a match, where with without replacement the untreated individual is considered only once. For each treated observation, i, a control observation, j, that has the closest x is selected. A disadvantage is the risk of bad matching, if the closest neighbour is far away (Katchova, 2013).

RADIUS

Each treated unit is matched with a control unit whose propensity score falls within a specified radius (Becker & Ichino, 2002). An advantage of this method is that it uses only as many comparison units as are available within the radius and therefore allows for usage of extra (fewer) units when good matches are (not) available. It avoids the risk of bad matches, but oversampling is possible (Katchova, 2013).

STRATIFICATION AND INTERVAL MATCHING

Stratification and interval matching compare the outcomes within intervals or blocks of propensity scores (Katchova, 2013). The difference between the average outcome of the treated and the control is calculated in each interval (Becker & Ichino, 2002). The ATT is calculated as an average of the ATT for each block with weights given by the distribution of treated units across blocks (Becker & Ichino, 2002). A disadvantage of the Stratification model is that observations that are not present in the blocks are ignored.

Given the discussion of the propensity score matching, the next section will explain how propensity score matching was applied in this study.

APPLICATION OF PROPENSITY SCORE MATCHING

To successfully evaluate the effect of physical counting on predation losses a number of steps should be followed. The first step is to use a t-test to determine if a significant difference exists between predation losses associated with physical counting (treatment) and estimating (control); the t-test is performed by fitting a regression. Predation losses are used as the dependent variable and the independent variable consists of a dummy variable that is used to indicate if wildlife ranchers use physical counting (variable take a value of one). Once it has been confirmed that a significant difference exists between physical counting and estimating (coefficient is significant) the propensity scores are estimated.

Propensity scores are estimated with the use of a Logit or Probit model where the dependent variable is the level of predation losses while the independent variable consists of factors that affects or determines the predation losses (hypothesised). The Logit/Probit model predicts conditional probability of treatment for all the wildlife ranchers. The estimate propensity scores are then used to match wildlife ranchers who use physical counting to wildlife ranchers who estimate numbers based on similar characteristics. Matching is done based on the estimation of the average effect of treatment on the treated (ATT). The matching procedure tests whether the mean propensity score and other covariates between physical counting and estimating are the same (Lance, Guilkey, Hattori & Angeles, 2014). To ensure that the matching is done correctly a region of common support is identified (Katchova, 2013). The region of common support requires that counterparts can be found for physical counting between the ranchers who estimate wildlife numbers. Matching is done using nearest neighbour, radius, kernel and stratified matching.

Testing the statistical significance of treatments and calculating their standard errors lead to a problem; the variance due to the calculation of the propensity scores is not included in the t-test (Caliendo & Kopeinig, 2005). One method to overcome this problem is by using bootstrapping (Lechner, 2002) where bootstrapping improve (increase) the confidence interval and therefore reduce the margin of error of the matching process. Propensity score matching was performed in STATA (Lechner, 2002).

3.6 VARIABLES HYPOTHESISED TO INFLUENCE PREDATION

The variables that were considered in this dissertation and their hypothesised direction of influence can be seen in Tables 3.2, 3.3, 3.4. These variables will be tested to identify which have a significant influence on predation, whether it is the occurrence and/or level of predation and their expected influence. The variables that affect the level of predation can be seen as the factors enhancing or reducing the level of predation. The specific factors, influencing the level, will usually consist of non-lethal and lethal control methods. Control methods are a controversial topic and a variety of opinions exists with regard to the effectiveness of predator control methods (McAdoo & Glimp, 2000). Variables can be divided into four groups; the wildlife rancher and rancher's perception, managerial factors, non-lethal, and lethal control methods. The wildlife rancher and rancher's perception includes the characteristics of the wildlife rancher, the wildlife ranch and what predators are perceived to be causing damage. Management factors includes the decisions made by the wildlife ranchers to control predation. The control methods include lethal control methods and methods assisting wildlife ranchers to prevent predation as well as lethal control methods.

Table 3.2 Wildlife rancher and rancher's perception variables hypothesised to influence predation and the expected influence

VARIABLE	DESCRIPTION	EXPECTED INFLUENCE
Wildlife rancher and rancher's perception		
Age of wildlife ranchers	Continuous variable	-
Black-back jackal as a priority predator	Dummy variable, coded 1 for black-back jackal as priority, 0 otherwise	+
Caracal as a priority predator	Dummy variable, coded 1 for caracal as priority, 0 otherwise	+
Leopard as a priority predator	Dummy variable, coded 1 for leopard as priority, 0 otherwise	+
Brown hyaena as a priority predator	Dummy variable, coded 1 for brown hyaena as priority, 0 otherwise	+
Other farm enterprises: Cattle	Dummy variable, coded 1 for cattle, 0 otherwise	-
Other farm enterprises: Sheep	Dummy variable, coded 1 for sheep, 0 otherwise	-
Other farm enterprises: Both (cattle and sheep)	Dummy variable, coded 1 for both (cattle and sheep), 0 otherwise	-

Table 3.3 Physical attributes of the wildlife ranches and managerial factor variables hypothesised to influence predation and the expected influence

VARIABLE	DESCRIPTION	EXPECTED INFLUENCE
Managerial factors		
Size of the wildlife ranch (ha)	Continuous variable	+
Topography of the wildlife ranch: Mountainous	Dummy variable, coded 1 for mountainous, 0 otherwise	+
Topography of the wildlife ranch: Hills	Dummy variable, coded 1 for hills, 0 otherwise	+
Topography of the wildlife ranch: Plains	Dummy variable, coded 1 for plains, 0 otherwise	-
Topography of the wildlife ranch: Karoo	Dummy variable, coded 1 for karoo, 0 otherwise	-
Topography of the wildlife ranch: Bush veld	Dummy variable, coded 1 for bush veld, 0 otherwise	+
Topography of the wildlife ranch: Savannah	Dummy variable, coded 1 for savannah, 0 otherwise	-
Carcasses as indication of predation	Dummy variable, coded 1 for carcasses, 0 otherwise	+
Wildlife counts as indication of predation	Dummy variable, coded 1 for wildlife counts, 0 otherwise	-
Numbers hunted as indication of predation	Dummy variable, coded 1 for numbers hunted, 0 otherwise	-
Frequency of owner on the wildlife ranch: Permanent	Dummy variable, coded 1 for permanent, 0 otherwise	-
Frequency of owner on the wildlife ranch: Weekly	Dummy variable, coded 1 for weekly, 0 otherwise	-
Frequency of owner on the wildlife ranch: Two-weekly	Dummy variable, coded 1 for two-weekly, 0 otherwise	+
Frequency of owner on the wildlife ranch: Other	Dummy variable, coded 1 for other, 0 otherwise	+
Frequency of manager on the wildlife ranch: Permanent	Dummy variable, coded 1 for permanent, 0 otherwise	-
Frequency of manager on the wildlife ranch: Weekly	Dummy variable, coded 1 for weekly, 0 otherwise	-
Frequency of manager on the wildlife ranch: Two-weekly	Dummy variable, coded 1 for two-weekly, 0 otherwise	+
Frequency of manager on the wildlife ranch: Other	Dummy variable, coded 1 for other, 0 otherwise	+
Frequency of personnel on the wildlife ranch: Permanent	Dummy variable, coded 1 for permanent, 0 otherwise	-
Frequency of personnel on the wildlife ranch: Weekly	Dummy variable, coded 1 for weekly, 0 otherwise	-
Frequency of personnel on the wildlife ranch: Two-weekly	Dummy variable, coded 1 for two-weekly, 0 otherwise	+
Frequency of personnel on the wildlife ranch: Other	Dummy variable, coded 1 for other, 0 otherwise	+

Table 3.4 Control or preventative method variables hypothesised to influence predation and the expected influence

VARIABLE	DESCRIPTION	EXPECTED INFLUENCE
Control methods		
Non-lethal control methods and methods assisting wildlife ranchers		
Electric fences	Dummy variable, coded 1 for electric fences, 0 otherwise	-
Lights and/radios	Dummy variable, coded 1 for lights and/radios, 0 otherwise	-
Cameras	Dummy variable, coded 1 for cameras, 0 otherwise	-
Overall use of cage traps	Dummy variable, coded 1 for cage traps, 0 otherwise	-
Game rangers	Dummy variable, coded 1 for game rangers, 0 otherwise	-
Guarding animals	Dummy variable, coded 1 for guarding animals, 0 otherwise	-
Lethal control methods		
Overall use of shooting	Dummy variable, coded 1 for shooting, 0 otherwise	-
Overall use of poison	Dummy variable, coded 1 for poison, 0 otherwise	-
Overall use of foothold traps		
Shooting:	Dummy variable, coded 1 for foothold traps, 0 otherwise	-
• Predator management through: Specialist hunter	Dummy variable, coded 1 for specialist hunter, 0 otherwise	-
• Predator management through: Hunter	Dummy variable, coded 1 for hunter, 0 otherwise	-
• Predator management through: Owner	Dummy variable, coded 1 for owner, 0 otherwise	-
• Predator management through: Personnel	Dummy variable, coded 1 for personnel, 0 otherwise	-

WILDLIFE RANCHER AND RANCHER'S PERCEPTION

It was hypothesised that all the variables in this group, except for predators seen as a priority, will have a negative effect on predation. Older wildlife ranchers have more knowledge regarding predators and know what predators causes damage on their wildlife ranches, therefore these damage causing animals can be targeted. If a wildlife rancher also farms with cattle, sheep or both, it is expected that predation on wildlife will decrease, because domesticated animals is targeted easier.

MANAGERIAL FACTORS

It is expected that the larger the wildlife ranch the more predation will be incurred and wildlife ranches that are more open will have less predation than wildlife ranches consisting of mostly mountains, hills and bush veld. Carcasses as an indication are hypothesised to increase predation because predators are lured to the carcass, other methods of indicating predation will reduce predation. It is expected that predation will decrease with more human activity, whether it is the owner, managers or personnel.

CONTROL METHODS

NON-LETHAL METHODS, METHODS ASSISTING WILDLIFE RANCHERS AND LETHAL CONTROL METHODS

Non-lethal, methods assisting wildlife ranchers and lethal control methods were hypothesised to have a decreasing effect on predation in the Limpopo province. It is expected that non-lethal methods will reduce the occurrence of predation. For example, if wildlife ranchers make use of non-lethal methods such as jackal proof fences, they will keep certain predators out and thus the occurrence of these predators predating on wildlife. Lethal methods will reduce the level of predation; because predators are killed their numbers will decline, as well as the number of attacks, although attacks will still occur since new predators can enter the wildlife ranch.

This short discussion on the hypothesised variables affecting either the occurrence or the level of predation on wildlife; concludes Chapter 3. The results obtained in this dissertation by means of the methodology are discussed in Chapter 4.

CHAPTER 4
Results

4.1 INTRODUCTION

This chapter discusses the results obtained by implementing the methodology described in the previous chapter. Firstly, the economic implications of predation in the wildlife industry in the Limpopo province, South Africa are discussed; economic implication of predation relates to the direct and indirect cost, secondly, the factors influencing the occurrence and level of predation are discussed, and thirdly, propensity score matching is discussed.

4.2 DESCRIPTIVE STATISTICS OF THE LIMPOPO PROVINCE AND THE WILDLIFE RANCHERS

As discussed previously, 201 wildlife ranchers (all being members of WRSA) in the Limpopo province were interviewed by telephone. These wildlife ranchers represent a 23% proportional sample of the more than 800 members of WRSA in the Limpopo province. The majority of the wildlife ranchers in the Limpopo province were between the ages of 46 and 55 and 96% of wildlife ranchers were male. The average size of a wildlife ranch in the Limpopo province is 2 152.5 ha; wildlife ranch sizes varying between 58 ha (min) and 37 000 ha (max).

A total of 111 respondents indicated that the topography of their wildlife ranches comprised only bush veld and 171 respondents indicated that the topography consists of bush veld, as well as mountains, hills, plains and/or savannah. Therefore it suggests that a large proportion of the Limpopo province is predominantly bush veld. A few wildlife ranchers also engaged in other enterprises namely: 32 wildlife ranchers indicated that they also farm with cattle, six wildlife ranchers farm with sheep and six indicated that they farm with both cattle and sheep; other enterprises indicated by respondents in the survey included fruit, vegetables and irrigation.

A summary of the wildlife ranchers and the ha utilised for wildlife ranching is provided in Table 4.1. The Limpopo province consists of 8 847 848 ha of grazing land, which is 74% of the total area in the province (Abstract, 2015). In this dissertation a total of 23.29% of the wildlife ranchers in Limpopo province were interviewed, thus representing 4.89% of the available savannah in the survey.

Table 4.1 Number of wildlife ranchers surveyed and the hectares utilised in the Limpopo province

	Surveyed	Limpopo province	Percentage
Wildlife ranchers	201	863	23.29
Wildlife ranches (ha)	432 647	8 847 848	4.89

Source: Abstract, 2015

Wildlife ranchers had a choice between four options on their method of counting wildlife. The four options and the number of wildlife ranchers that chose each option are given in Table 4.2. The majority of the wildlife ranchers indicated that they estimate wildlife numbers, suggesting that they do not know precisely how many head of wildlife they have, followed by physical counting of wildlife. Wildlife ranchers who physically count wildlife know the exact numbers on the wildlife ranches. Only three wildlife ranchers chose the forth option, which is the number of wildlife available to hunt. It is important to note that none of the wildlife ranchers in the Limpopo province chose the second option, namely a Rand value.

Table 4.2 Options used by wildlife ranchers to establish the numbers of wildlife in the Limpopo province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	65	0	133	3
Percentage of the Province	32.34	0	66.17	1.49

As stated previously in the methodology; antelope was divided into three groups, namely, large species, small species and scarce species/colour variants. These antelope species were chosen based on the extent of predation incurred by wildlife ranchers; the five species most predated on in each group were chosen and are illustrated in Table 4.3.

Table 4.3 Three defined groups of antelope species

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Kudu	*Tragelaphus strepsiceros*	Impala	*Aepyceros melampus*	Livingston eland	*Tragelaphus oryx*
Nyala	*Tragelaphus angasii*	Blesbok	*Damaliscus pygargus*	Black impala	*Aepyceros melampus*
Blue wildebeest	*Connochaetes taurinus*	Bushbuck	*Tragelaphus scriptus*	Golden wildebeest	*Connochaetes taurinus*
Gemsbok	*Oryx gazelle*	Rhebok	*Redunca fulvorufula*	King wildebeest	*Connochaetes taurinus*
Red hartebeest	*Alcelaphus buselaphus*	Reedbuck	*Redunca arundinum*	Yellow blesbok	*Damaliscus pygargus*

4.3 ENUMERATOR'S PERSONAL OPINION

A single experienced enumerator was used to conduct the survey by telephone with the wildlife ranchers and complete the questionnaires. The enumerator used the structured questionnaire described briefly in the methodology. The perception of the enumerator as established during the telephone interviews was considered very valuable and a short summary is noted in this section.

According to the enumerator the extent of the wildlife industry came as a surprise. It seems damage causing animals are not always controlled because a substantial number of wildlife ranchers do not live permanently on the wildlife ranches. Wildlife ranchers that live permanently on the wildlife ranches usually have automatic cameras at water points to estimate the number of leopards on the wildlife ranch. A wildlife rancher from Thabazimbi indicated that he identified five leopards in one night. Leopards are endangered, but they are abundant in the Limpopo province. Many wildlife ranchers feel that more hunting permits, particularly for leopards that could be hunted by overseas hunters, should be granted annually. If wildlife ranchers are compensated for the legal hunting of leopards, it will lead to wildlife ranchers protecting the species that may ensure the species' survival in the future.

According to the enumerator the abolition of an official damage causing hunting organization, such as the Free State Problem Animal Hunting Club (better known as "Oranjejag"; Ferreira, 1988), is mourned by many wildlife ranchers and fuels the perception that predators such as the black-back jackal and caracal are becoming a major problem; the situation is completely out of control. Sheep farmers began converting to cattle farming and wildlife ranching due to the effect of livestock theft and damage causing animals. According to the enumerator, it is perceived by wildlife ranchers that cattle farmers do not apply predator control management practices and it contributes to the problems that wildlife ranchers are experiencing with predation. Wildlife ranchers are making more use of camp systems to protect expensive species such as nyalas which are easy prey for any predator. According to the enumerator the effect of the brown hyaena is underestimated; they are also a major damage causing animal in the Limpopo province. One wildlife rancher saw on his cameras how two brown hyaenas trapped an antelope in the corner of the camp and kill it. African buffalo (*Syncerus caffer*), as well as antelope species that keep their young apart from the rest of the group, are soft targets for especially leopards. Leopards attack buffalo calves while cows are calving and in many instances the buffalo cow is also killed. Caracal also has the ability to kill much larger antelope species than the black-back jackal. Losses due to predation are incurred throughout the year but especially in lambing season, because predators reproduce at this time and need to provide food to their young. Losses due to predators are very high and in many cases the losses are several millions of ZAR on a single wildlife ranch. Wildlife ranchers indicated that colour variants are caught first. Pythons are also a predator contributing to the losses.

Apparantly, wildlife ranchers are increasingly moving to jackal proof fences, Bonox and electrical fences, which is very expensive. On large wildlife ranches plains game is predated on the most. On large wildlife ranches, especially in mountainous areas, predators are difficult to control. One wildlife rancher indicated that he tows the guts and skins of slaughtered animals behind his truck at dusk and then waits approximately an hour before he returns on the same route. This allows him to shoot black-back jackal that is lured by the smell of blood.

It was alleged that a poison is legally available which only kills black-back jackal and caracal and that other animals that may scavenge on the dead carcasses of these black-back jackal and caracal will not die. Wildlife ranchers are very protective of vultures and are passionate about conservation. Cage traps are a very effective way to catch caracal, because they are very curious and are easily lured with bait.

Wildlife ranchers have their hands in their hair regarding the Limpopo Department of Nature Conservation. Several wildlife ranchers said that if the department remove endangered species, such as leopard, on their wildlife ranches, they just free the animals beyond the gates of the wildlife ranch, which means that the same leopard that predated in the first instance will be back at the wildlife ranch the same night. Private game reserves do nothing to control problem animals and there were at least three wildlife ranchers who told the enumerator that they incurred major losses due to wild dogs (*Lycaon pictus*).

A year or two ago it was predicted that a bubble in the wildlife industry would burst sooner rather than later, and new wildlife ranchers are now encouraged to ranch with colour variants. Wildlife ranchers are very positive about the wildlife industry, even though prices decreased this year for example the price of black impala (*Aepyceros melampus*). Wildlife ranchers still feel that the wildlife industry is profitable.

It is perceived that the wildlife industry might be manipulated by a few large wildlife ranchers. Some four years ago waterbuck (*Kobus ellipsiprymnus*) was very expensive but because they did not thrive as desired, the prices decreased. The price of nyalas (*Tragelaphus angasii*) suddenly increased from ZAR 6 000 (2013) to ZAR 30 000 (2014). The golden wildebeest (*Connochaetes taurinus*) is the next species becoming very popular and expensive and more recently also kudu (*Tragelaphus strepsiceros*). Smaller antelope such as the small five, consisting of steenbok *(Raphicerus campestris*), red, grey and blue duikers (*Cephalophus natalensis, Sylvicapra grimmia* and *Philantomba monticola,* respectively) and suni (*Neotragus moschatus*) are becoming very popular. A ram and two ewes are kept in 0.5

ha camps and at a recent small five auction which was held in Thabazimbi, they attracted wide interest and these small antelope achieved very high prices. It is surprising how many antelope can be kept on a few hectares.

4.4 THE COST OF PREDATION IN THE LIMPOPO PROVINCE

The cost of predation can be divided into direct and indirect costs. The direct cost is associated with number of antelope lost due to predation. As discussed in the methodology it is very difficult to allocate a value (ZAR) to antelope because it is not as standardized as cattle or sheep.

4.4.1 DIRECT COST OF PREDATION IN THE LIMPOPO PROVINCE

The average loss of each species per wildlife rancher for the dissertation was calculated as well as the average ha that is ranched with for each species. These losses are presented in Table 4.4.

There are more than 800 members of WRSA in the Limpopo province and 201 of them were contacted telephonically for the survey (Column 1). The number and percentage of wildlife ranchers owning the specific species in each of the three groups (large species, small species and scarce species/colour variants) are indicated in Column 2 and 3, respectively. Kudu (69.18%) and nyala (56.22%) were the two species, in the large species group, that were owned by most wildlife ranchers. Impala (83.08%) was by far the most frequently owned species in the small antelope group followed by blesbok (30.85%) and bushbuck (15.92%). Very few wildlife ranchers indicated that they own reedbuck and rhebok, but they incurred a large number of predation in comparison with other small wildlife species. In the small species/colour variants group the majority of the wildlife ranchers indicated that they own black impala (13.93%) followed by golden wildebeest (9.45%). The number of wildlife ranchers indicating that they own scarce species/colour variants is markedly lower (13.93% was the highest percentage) than the number that indicated large species (56.22% highest percentage) or small species (83.08% was the highest percentage).

Table 4.4 A summary of average hectares and average losses of antelope calculated for the Limpopo province

	Sample size Column 1	Wildlife ranchers owning species Column 2	% Wildlife ranchers owning species Column 3	Number of individual animals lost due to predation Column 4	Average ha Column 5	Average number of each species lost/wildlife rancher Column 6	Average number of wildlife lost/ha Column 7
Large species							
Nyala	201	113	56.22	1 009	2 147.09	8.93	0.00416
Blue wildebeest	201	66	32.84	354	2 436.17	5.36	0.00220
Kudu	201	139	69.15	1 400	2 520.85	10.07	0.00399
Gemsbok	201	31	15.42	332	3 668.23	10.71	0.00292
Red hartebeest	201	33	16.42	186	2 249.36	5.64	0.00251
Small species							
Impala	201	167	83.08	8 178	2 265.05	48.97	0.02162
Rhebok	201	6	2.99	34	6 730.00	5.67	0.00084
Bushbuck	201	32	15.92	295	1 754.44	9.22	0.00526
Reedbuck	201	6	2.99	16	1 150.83	2.67	0.00232
Blesbok	201	62	30.85	1 095	1 905.67	17.66	0.00927
Scarce species/colour variants							
Black impala	201	28	13.93	67	2 166.75	2.39	0.00110
Golden wildebeest	201	19	9.35	43	930.05	2.26	0.00243
King wildebeest	201	2	0.96	9	1 270.00	4.50	0.00354
Livingston eland	201	15	7.46	103	1 671.07	6.87	0.00411
Yellow blesbok	201	1	0.50	6	1 000.00	6.00	0.00600

The total number of antelope lost in each species group is indicated in Column 4. Following the numbers lost is the average ha ranched with for each species (Column 5). It does not mean if the average ha for nyalas, for example, is 2 147 ha that the wildlife rancher only ranch with nyalas, there can be other species present as well. Column 6 is the average number each species lost due to predation per wildlife rancher. Column 7 is the average number lost per ha (calculated by dividing the average loss of each species per wildlife rancher by the average ha). This loss per hectare can be used to calculate the losses due to predation for each wildlife ranch.

The costs incurred with predation can be ascribed to the range of predators that are found in the Limpopo province. The predators that are implicated by the wildlife ranchers for predation losses in each of the three antelope groups are given in Figures 4.1, 4.2 and 4.3.

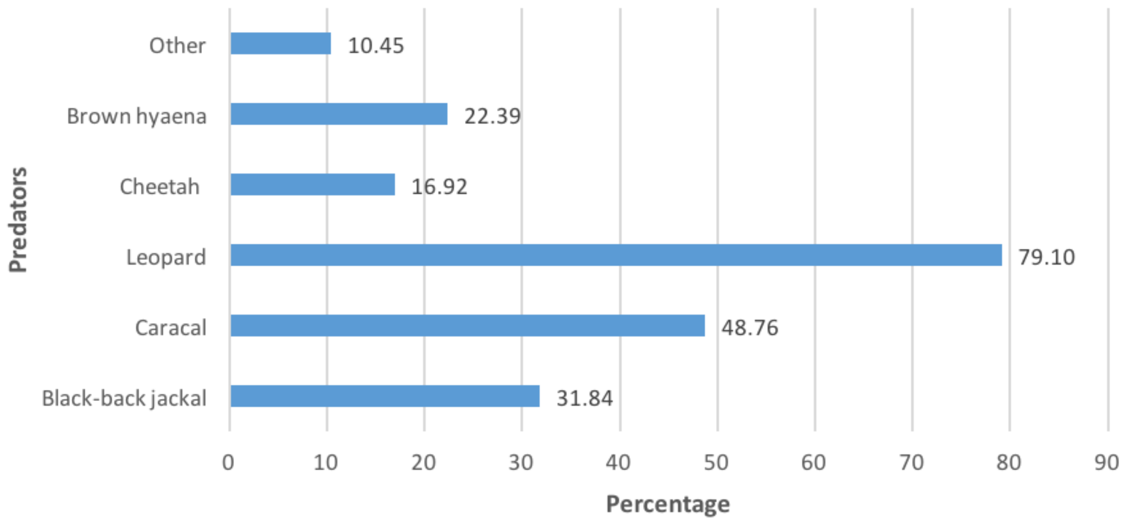

Figure 4.1 Predators implicated for losses on large antelope species on wildlife ranches of WRSA members in the Limpopo province

According to the wildlife ranchers, almost 80% (Figure 4.1) indicated that predation due to leopard was the main cause of losses on large antelope species followed by caracal and black-back jackal. “Other” in Figure 4.1 includes predators such as python, baboon, lion, wild dog and stray dogs and spotted hyaena.

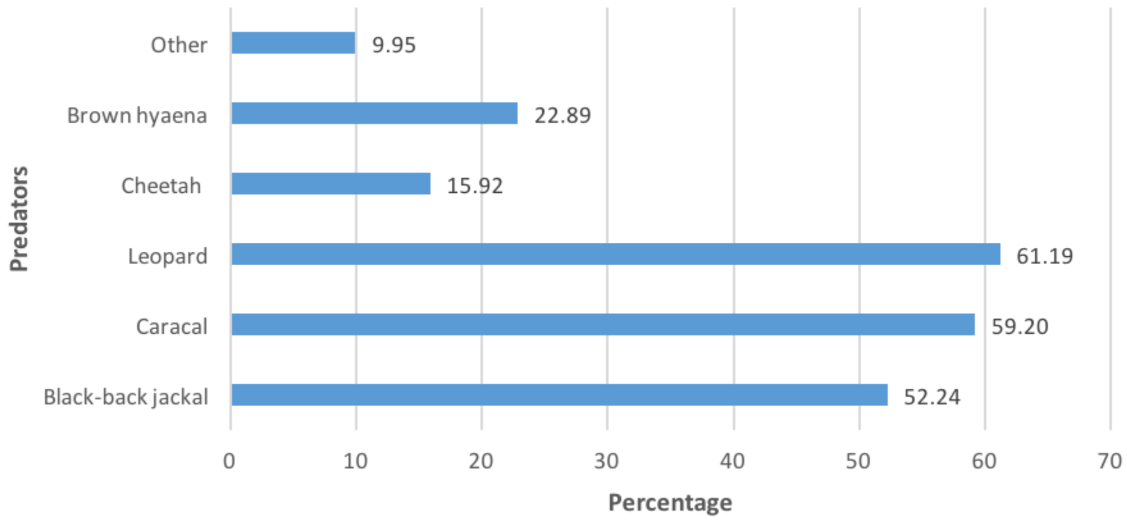

Figure 4.2 Predators implicated for losses on small antelope species on wildlife ranches of WRSA members in the Limpopo province

The percentage of wildlife ranchers that indicated that leopard and caracal are the major damage causing animals is about the same for small antelope species (Figure 4.2). The black-back jackal accounts for just over 50% of the losses. The "Other" in Figure 4.2 includes predators such as python, baboon, lion, spotted hyaena, wild dog, stray dogs and eagle.

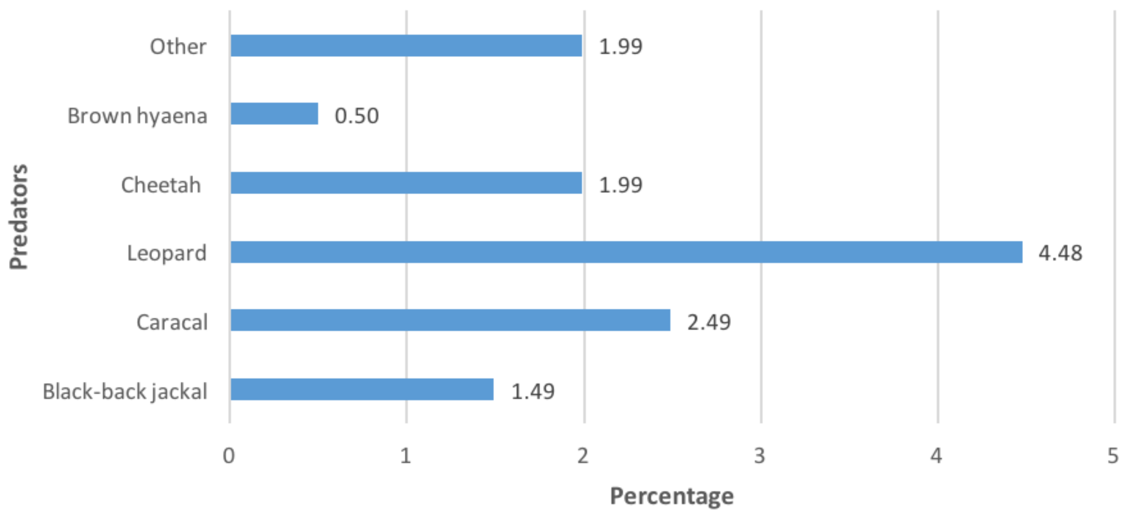

Figure 4.3 Predators implicated for losses on scarce species/colour variant antelope on wildlife ranches of WRSA members in the Limpopo province

For the scarce species/colour variant antelope the majority of wildlife ranchers indicated that leopard is the main damage causing animal (Figure 4.3). The cheetah plays a larger role than the black-back jackal in the case of scarce species/colour variant antelope. The “Other” in Figure 4.3 includes python and wild dog.

According to the wildlife ranchers leopard was the major damage causing animal for all three groups, followed by caracal. Cheetah had a larger impact on scarce species/colour variants than black-back jackal, but a smaller impact on large and small antelope.

4.4.2 INDIRECT COST OF PREDATION MANAGEMENT IN THE LIMPOPO PROVINCE

The indirect cost of predation includes all the costs associated with the prevention of predation. It is very difficult to accurately determine these costs because wildlife ranchers forget to include additional costs such as fuel and labour, to name a few.

The wildlife ranchers were asked to indicate their total cost of predation management. This amount includes non-lethal control methods and methods assisting wildlife ranchers and lethal methods of control. The total amount for the dissertation was ZAR 7 467 530. The dissertation was conducted on 201 wildlife ranches comprising total 432 647 ha. Therefore the average indirect cost of predation for the dissertation can be calculated as the total cost of predation management of the disseratation divided by the total ha of the dissertation multiplied with the percentage of wildlife ranchers using predation management methods. The total indirect cost/ha for the Limpopo province was calculated as ZAR 26.15/ha.

The percentage of wildlife ranchers using methods to control predation is shown in Figure 4.4. Surprisingly, more wildlife ranchers use control methods (66%) than the 37% of cattle farmers reported in a study in the North West province (Badenhorst, 2014). This relatively high percentage, compared to cattle farmers, are ascribed to the fact that fences (electric, jackal proof and wire mesh) are routinely included as a control method by wildlife ranchers.

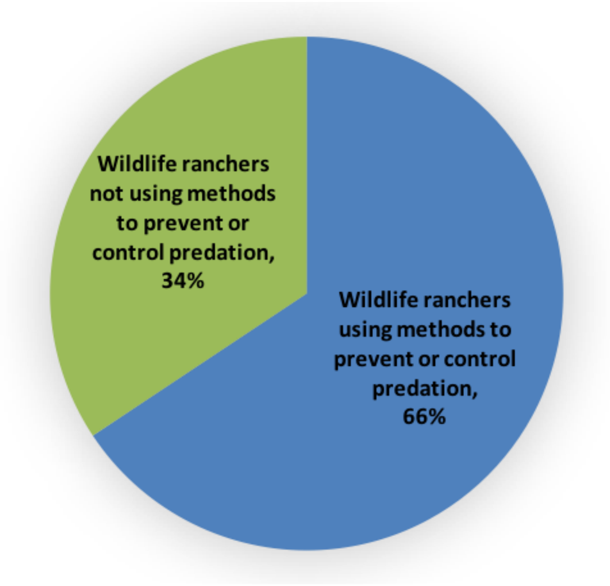

Figure 4.4 Percentage of WRSA members using predation management methods in the Limpopo province

The number of wildlife ranchers and type of lethal control methods used by them in the disseratation are presented in Figure 4.5. Most of the wildlife ranchers make use of shooting to control predators. Very few wildlife ranchers make use of foothold traps and poison. The low number of wildlife ranchers that indicated they make use of foothold traps and poison are ascribed to wildlife ranchers being scared of admitting to the use of these methods due to government regulation.

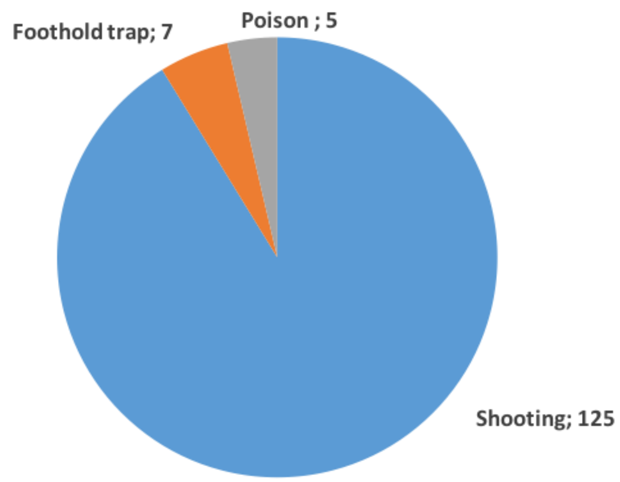

Figure 4.5 Number of WRSA members using lethal control methods to control predators in the Limpopo province

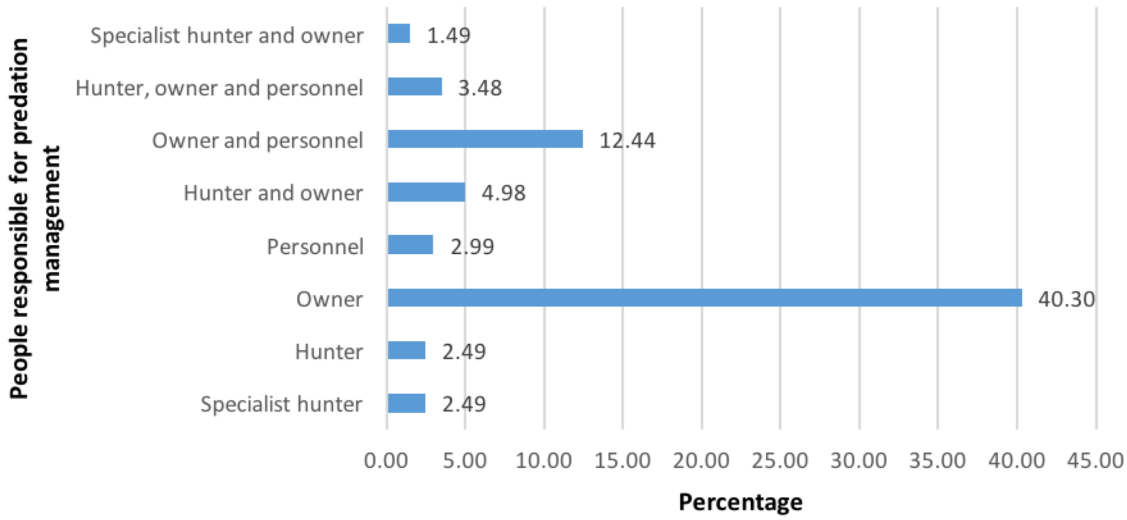

Figure 4.6 Percentage of people responsible for managing predation on the wildlife ranches of WRSA members in the Limpopo province

In Figure 4.6 it is indicated who is responsible for managing predation on the wildlife ranches (percentage). A substantial proportion of 40.3% of the wildlife ranchers (as owners) are responsible for managing predation. Fewer specialist hunters are used than the 16% reported when managing predation on cattle farms in the North West province (Badenhorst, 2014); one reason is that wildlife ranchers are generally assumed to be good hunters and therefore are more inclined to do their own hunting of predators.

The number of wildlife ranchers and type of non-lethal methods and methods assisting wildlife ranchers used by them are shown in Figure 4.7. It is not surprising that wildlife proof fencing and electric fences are the most widely used non-lethal method because of specific regulations applicable to the wildlife ranching industry regarding fences. Cameras are also widely used by wildlife ranchers, other methods include, game rangers, lights and/or radios, cage traps and guarding animals such as donkeys.

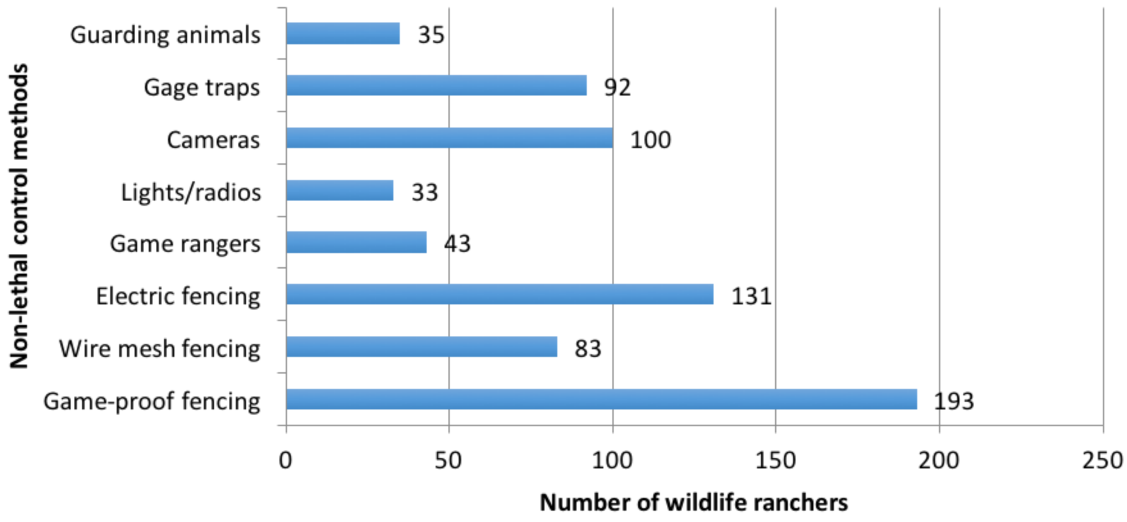

Figure 4.7 **Number of WRSA members using non-lethal control methods and methods assisting wildlife ranchers to manage predation in the Limpopo province**

It is important that wildlife ranchers have direct and indirect costs information that are easy to interpret; the results regarding the direct and indirect costs must be easy to interpret by the wildlife ranchers, therefore three scenarios, specifically for the Limpopo province, are presented. The average numbers lost/ha have been presented in Column 7 of Table 4.4 and these values will be used in the calculations as well as the indirect cost calculated in 4.4.2. The prices of wildlife fluctuate considerably, therefore an average price was calculated from the national auction prices [Personal communication: Dr. Johann Reyneke (WildSA & Gamelab) & Dr. Paul Lubout (Wildlife Stud Services & Gamelab), December 2015] for those species listed by the wildlife ranchers in this study (**Appendix H**). These ZAR values have been used to calculate the direct cost in each of the scenarios.

The following scenarios are examples of how the total cost for the three different wildlife species groups can be calculated.

Scenario 1 (Large antelope species)

Assuming a wildlife rancher has nyalas (amongst other species) on 5 000 ha, he/she can have an average loss of 21 nyalas/year (5 000 ha x 0.00416). The direct cost is then estimated to be ZAR 507 465/year (ZAR 24 165). The indirect cost is calculated as ZAR 26.15/ha multiplied with 5 000 ha, which gives an amount of ZAR 130 750. Therefore; in this scenario the total cost for this specific wildlife ranch in the Limpopo province is ZAR 638 215/year.

Scenario 2 (Small antelope species)

If a wildlife rancher keep blesbok on a 12 000 ha ranch, he/she can expect an average loss of 111 blesbok/year (12 000 ha x 0.00927). The direct cost is then ZAR 460 983/year (ZAR 4 153/ewe). The indirect cost is calculated to be ZAR 313 800 (ZAR 26.15 x 12 000 ha). Therefore, in this scenario the estimated total cost is ZAR 774 783/year for a wildlife ranch in the Limpopo province.

Scenario 3 (Scarce species/colour variants)

If a wildlife ranch is 6 000 ha and a wildlife rancher has black impala as well as Livingston eland; he/she can expect an average annual loss of seven black impala (6 000 ha x 0.00110) and 25 Livingston eland (6 000 ha x 0.00411). The direct cost on this wildlife ranch is estimated to be ZAR 11 854 077. (Black impala was valued at ZAR 684 761 and Livingston eland valued at ZAR 282 430). The indirect cost is estimated to be ZAR 156 900/year (ZAR 26.15 x 6 000 ha). The total cost in this scenario is calculated as ZAR 12 010 977/year for this specific wildlife ranch in the Limpopo province.

4.5 FACTORS INFLUENCING PREDATION IN THE LIMPOPO PROVINCE OF SOUTH AFRICA

As already stated the wildlife species (antelope) were divided into large species, small species and scarce species/colour variant antelope. The factors affecting the occurrence and level of predation within each group will be discussed in depth. It was hypothesised that the variables affecting the occurrence and the level of predation are different. The variables that influence the occurrence of predation are all the variables that can prevent predation and the variables that have an influence on the level of predation are those that can reduce the level of predation.

The decision to determine if it is one decision or two decisions are based on the significance of the Cragg's test. If the results are significant the Double hurdle model (Probit and Truncated models) is appropriate; meaning the variables affecting the occurrence and level of predation is different. If the results are insignificant the Tobit will be appropriate; meaning the variables effecting the occurrence and level of predation are the same. For the Limpopo province the Cragg's test statistic for all three groups are significant at a 10% significance level; therefore the Probit (occurrence) and Truncated (level) models' results will be discussed. A significance level of 10% is acceptable because the aim is not to predict probabilities, but rather to identify characteristics and actions associated with a lower probability of occurrence and level of predation.

To determine the underlying structure in the predation management practices, backward regression was used in this study. It was done to reduce the data size and was conducted for all three groups (large species, small species and scarce species/colour variant antelope).

4.5.1 PREDATION ON LARGE ANTELOPE SPECIES

The results for the Tobit, Double Hurdle model and the Cragg's test statistic for predation on large antelope are given in Table 4.5. The Cragg's test statistic of 89.056 is significant (**ρ**=0.000) therefore it is two decisions. Firstly, the variables that have an influence on the occurrence of predation for large antelope will be discussed (Probit) and secondly the variables that have an influence on the level of predation (Truncated) in terms of the wildlife rancher and his/her perception, the managerial factors and the non-lethal and lethal control methods used. Although the Tobit will not be discussed, the coefficients and significance of the variables of the Tobit is also shown.

Table 4.5 Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on large species

	Large species					
	Tobit		Probit		Truncated	
	Coefficient	P value	Coefficient	P value	Coefficient	P value
Wildlife rancher and rancher's perception						
Age 36-45	1.206	0.228	-0748	0.455	2.897	**0.004***
Male	-0.505	0.614	1.255	0.210	-2.197	**0.028***
Wildlife ranch size	-0.497	0.619	-0.329	0.742	1.072	0.284
Topography: Mountainous	2.375	**0.018***	2.195	**0.028***	1.108	0.268
Topography: Bush veld	2.219	**0.027***	2.672	**0.008***	-0.868	0.386
Black-back jackal as a priority predator	1.821	**0.069***	0.055	0.956	1.886	**0.059***
Cheetah as a priority predator	1.352	0.176	1.657	**0.097***	0.080	0.936
Managerial factors						
Carcass as indication of predation	-1.036	0.300	1.889	**0.059***	-3.975	**0.000***
Owner is less than twice a week on the wildlife ranch	0.453	0.651	-0.504	0.614	0.932	0.352
Control methods						
Non-lethal control methods and methods assisting						
Cage traps	-0.713	0.476	-0.201	0.841	-0.827	0.408
Electric fences	3.473	**0.001***	1.072	0.284	2.807	**0.005***
Lights and/or radios	-1.094	0.274	-0.045	0.964	-1.366	0.172
Black-back jackal caught in cage traps	1.609	0.108	0.613	0.540	0.248	0.804
Leopard caught in cage traps	0.494	0.622	-0.310	0.756	0.611	0.541
Lethal control methods						
Caracal poisoned	-0.880	0.379	0.292	0.771	0.959	0.338
Black-back jackal hunted by specialist hunter	1.093	0.275	-0.449	0.654	2.820	**0.005***
Caracal hunted by owner	2.623	**0.009***	0.123	0.903	3.400	**0.001***
Cragg's test statistic	89.056					
Significance	0.000					

Note: * statistical significance of 10 %

4.5.1.1 OCCURRENCE OF PREDATION OF LARGE ANTELOPE SPECIES

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

Results in Table 4.5 show that cheetah as a priority predator results in a higher (increased) occurrence of predation losses ($p<0.1$). This result is different from what was hypothesised. A potential explanation for this could be that cheetah is more prone in the research area and this could result in an increase of occurrence of predation by cheetahs. Mountains, bush veld and carcass as an indication of predation also result in increased losses ($p<0.1$) as expected.

NON-LETHAL, METHODS ASSISTING AND LETHAL CONTROL METHODS

The results show that none of the variables have an increasing or decreasing effect on the occurrence of predation ($p>0.1$); these results does not support the hypothesis. An explanation can be that those factors that do play a role in increasing or decreasing the occurrence of predation has not been tested for. A factor that could potentially affect the occurrence of predation is the presence of predators on the wildlife ranch or surrounding the wildlife ranch, although this has not been tested.

Secondly, the variables that have an influence on the level of predation on large antelope will be discussed in terms of the wildlife rancher and his/her perception, the managerial factors and the non-lethal and lethal control methods (Truncated).

4.5.1.2 LEVEL OF PREDATION ON LARGE ANTELOPE SPECIES

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

The results in Table 4.5 indicate that the following variables have an increasing effect on the level of predation: Age 36-45 and black-back jackal as priority predators ($p<0.1$) for wildlife ranchers. These variables support the hypothesis; together with male wildlife ranchers that has a decreasing effect on the level of predation ($p<0.05$).

Carcass as an indication of predation on the wildlife ranch has a decreasing probability on the level of predation on large antelope ($p<0.1$). This result is also different than hypothesised. The reason for this is that black-back jackal will rather scavenge food (when it is available) than hunting, because they are opportunistic predators.

NON-LETHAL, METHODS ASSITING AND LETHAL CONTROL METHODS

Electric fences have an increasing effect on the probability of the level of predation ($p<0.05$). This variable does not support the hypothesis; a possible reason is that predators are already inside the camps.

The decision that black-back jackal is hunted by a specialist hunter and the decision that a caracal is hunted by the owner result in an increase in the level of predation ($p<0.05$). These results are different than hypothesised. A reason is that shooting as a control method is not the most effective method to use to control black-back jackal, other methods can be more efficient.

4.5.2 PREDATION ON SMALL ANTELOPE SPECIES

The same method of discussion will follow for small antelope. The Cragg's test statistic of 18.072 is significant (**ρ**<0.1); therefore it is two decision. Firstly, the occurrence of predation on small antelope will be discussed (Probit) and secondly, the level of predation on small antelope (Truncated); as illustrated in Table 4.6. Information for the Tobit is also given, but will not be discussed.

4.5.2.1 OCCURRENCE OF PREDATION OF SMALL ANTELOPE SPECIES

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

As seen in Table 4.6 both black-back jackal and cheetah as priority predators and an owner that is only present on a weekly basis and not permanently have an increased effect on the occurrence of predation ($p<0.05$); which is in line with the hypothesis.

NON-LETHAL, METHODS ASSISTING AND LETHAL CONTROL METHODS

The only non-lethal method that has an effect on the occurrence of predation of small antelope is the overall use of cage traps ($p<0.1$). The overall use of cage traps has an increasing effect on the occurrence of predation; a possible reason is that other predators lure their mates when caught in a cage trap.

Table 4.6 Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on small species

	Small species					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Topography: Mountainous	0.569	**0.569**	1.165	**0.244**	-0.449	0.654
Topography: Bush veld	0.205	**0.837**	0.331	**0.741**	-0.133	0.894
Black-back jackal as a priority predator	2.948	**0.003***	2.875	**0.004***	1.173	0.241
Cheetah as a priority predator	2.070	**0.039***	1.853	**0.064***	0.931	0.352
Managerial factors						
Owner is weekly on the wildlife ranch	1.577	0.115	1.702	**0.089***	0.927	0.354
Control methods						
Non-lethal control methods and methods assisting						
Cage traps	3.457	**0.001***	2.663	**0.008***	1.725	**0.085***
Lights and/or radios	-1.906	**0.057***	-0.856	0.392	-1.723	**0.085***
Cameras	-1.627	0.104	-0.065	0.949	-2.099	**0.036***
Caracal caught in cage traps	-1.734	**0.083***	-1.623	0.105	-0.681	0.496
Lethal control methods						
Caracal poisoned	-516	0.606	-0.423	0.672	-0.205	0.837
Caracal hunted by owner	0.911	0.363	-0.167	0.868	1.095	0.273
Cragg's test statistic	18.750					
Significance	0.095					

Note: * statistical significance of 10 %

4.5.2.2 LEVEL OF PREDATION ON SMALL ANTELOPE SPECIES

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

None of these variables have an increasing or decreasing effect on the level of predation for small antelope ($p>0.1$). A possible reason can be that the wildlife rancher's perception and his/her management practices does not play a large role (Table 4.6).

NON-LETHAL, METHODS ASSISTING AND LETHAL CONTROL METHODS

Cage traps have an increasing effect on the level of predation ($p<0.1$), as with the occurrence of predation the reason can be that other predators lure their mates when caught in a cage trap. None of the lethal methods were significant. Lights and/or radios and cameras have a decreasing effect ($p<0.1$) on the level of predation on small antelope, which was expected.

4.5.3 PREDATION ON SCARCE/COLOUR VARIANT ANTELOPE

A discussion for scarce species/colour variant antelope species will now follow. The Cragg's test statistic of 26.386 is significant ($\boldsymbol{\rho}<0.05$); it will thus be two decisions and not one. The Probit and Truncated will be discussed in depth, but information for the Tobit is also given, as illustrated in Table 4.7.

4.5.3.1 OCCURRENCE OF PREDATION ON SCARCE SPECIES/COLOUR VARIANT ANTELOPE

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

Results in Table 4.7 show that the Age 56-65 has an increasing effect on the occurrence of predation ($p<0.1$) which is the opposite of what was hypothesised; a reason is that older wildlife ranchers hunt less than younger wildlife ranchers. Black-back jackal as a priority predator has a decreasing effect on the occurrence of predation ($p<0.1$) which also do not support the hypothesis, a possible reason is that the black-back jackal is diificult to target.

Table 4.7 Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on scarce species/colour variants

	Scarce species/colour variants					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Age 46 – 55	0.123	0.319	0.113	0.729	0.621	**0.013***
Age 56 – 65	0.370	**0.008***	0.855	**0.008***	0.275	0.237
Wildlife ranch size	-0.238	**0.237**	-0.474	**0.293**	-0.273	0.595
Black-back jackal as a priority predator	-0.233	**0.069***	-0.604	**0.056***	-0.041	0.765
Caracal as a priority predator	0.287	**0.039***	0.744	**0.029***	-0.147	0.313
Python as a priority predator	0.432	0.138	1.037	0.139	-0.450	0.108
Wild dog as a priority predator	0.578	**0.043***	1.870	**0.026***	-0.026	0.910
Managerial factors						
Number hunted as indication of predation	-0.257	**0.035***	-0.691	**0.019***	0.162	0.338
Control methods						
Non-lethal control methods and methods assisting						
Black-back jackal caught in cage traps	0.537	**0.017***	1.582	**0.004***	-0.047	0.823
Lethal control methods						
Owner manages predation	-0.101	0.351	-0.021	0.940	-0.425	**0.017***
Caracal hunted by owner	0.231	0.105	0.430	0.224	0.495	**0.055***
Cragg’s test statistic	26.386					
Significance	0.009					

Note: * statistical significance of 10 %

Caracal and wild dog as priority predators for wildlife ranchers have increasing effects on the occurrence of predation ($p<0.1$) of scarce/colour variants antelope; these results are the same as hypothesised. The number hunted as an indication of predation has a decreasing effect on predation ($p<0.05$), this variable support the hypothesis.

NON-LETHAL, METHODS ASSISTING AND LETHAL CONTROL METHODS

The black-back jackal caught in a cage trap results in an increasing effect on the occurrence of predation ($p<0.05$); a reason is because it is unlikely to catch a black-back jackal in a cage. None of the lethal methods were significant.

4.5.3.2 LEVEL OF PREDATION ON SCARCE SPECIES/COLOUR VARIANT ANTELOPE

WILDLIFE RANCHER AND HIS/HER MANAGEMENT PRACTICES

The results in Table 4.7 show that the only variable in this group that is significant is wildlife ranchers between the Age of 46-55 ($p<0.05$), but they cause an increase in the level of predation, which do not support the hypothesis, this might be because older wildlife ranchers hunt less than younger wildlife ranchers.

NON-LETHAL, METHODS ASSISTING AND LETHAL CONTROL METHODS

The owner managing predation has a decreasing effect on the level of predation ($p<0.1$), as hypothesised; however, caracal hunted by the owner has an increasing effect on the level of predation on scarce/colour variants antelope ($p<0.1$) this can be because cage traps are a better option for managing caracals than hunting (shooting).

Not many factors influenced the level of predation on small and scarce/colour variant antelope, whereas several variables influenced the level of predation on large antelope. Meaning that more factors have an increasing or decreasing effect, but also that more can be done for large antelope species than for the other two groups.

The variables that affect the three different groups also vary between them. Where non-lethal control methods and methods assisting will have a significant effect on the level of predation on small antelope, it will have no significant effect on large species (except for electric fences) nor on scarce species/colour variant antelope. None of the variables in the lethal control method group were even included in the analysis for large species or scarce/colour variant antelope.

As can be observed from the findings above; the variables that have an influence on the occurrence of predation is not the same as the variables that have an influence on the level of predation and this is true for all three groups. The findings support the conclusions of Van Niekerk (2010) and Badenhorst (2014) that the variables affecting the occurrence and the variables affecting the level of predation differs.

4.6 PROPENSITY SCORE MATCHING

To determine if there are a noteworthy difference between physical counting and estimating antelope as methods of estimating antelope numbers, the dissertation made use of propensity score matching. This was done for all three groups of antelope; the results of large antelope will be discussed first, followed by small and scarce/colour variant antelope.

4.6.1 LARGE ANTELOPE SPECIES

The first step of propensity score matching is to test if differences exist between physical counting and estimating of antelope and to estimate the propensity score that will be used for matching. The results for the t-test used to test for differences in physical counting and estimating are given in Table 4.8.

Table 4.8 T-test of large antelope species

Source	SS*	Df	MSS**		
Model	0.2904	1	0.2904	Prob > F	0.0000
Residual	2.6499	199	0.0133	R-squared	0.0988
Total	2.9403	200	0.0147	Adjusted R-square	0.0942

Level of predation	Coeff	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Treatment	0.0813	0.0174	4.67	**0.0000**	0.4695	0.1156
Constant	0.0645	0.0099	6.52	0.0000	0.0450	0.0840

The coefficient for treatment is positive (0.0813) and significant (0.0000) which means that the level of predation increase if antelope are physically counted. A reason for this can be that wildlife ranchers who physically count their wildlife have specific numbers (more accurate), which is not the case with estimating or wildlife species are placed under more stress when physically counted which makes them more susceptible to predators.

Next a Logit or Probit model is fitted to estimate the propensity score that will be used for matching. The propensity score is the conditional (predicted) probability of using physical counting based on some wildlife rancher and predation characteristics. Region for common support on which the propensity score matching will be done is 0.0006 to 0.9752, which mean that the coefficients will fall into this range. The final number of blocks is five, which indicates that the propensity scores are the same for the treated and control groups in each block.

The propensity scores estimated for every observation is used to find a match for physically counted observations. The results for the matching procedures are given in Table 4.9.

Table 4.9 Average effect of Treatment on the Treated (ATT) estimation with matching methods (Large species)

	Number of treatment groups	Number of control groups	ATT Before bootstrapping	ATT After bootstrapping	T-Statistic Before bootstrapping	T-Statistic After bootstrapping
Nearest Neighbour	63	39	0.088	0.088	3.261*	3.566*
			-0.027	-0.025		
Radius Matching	62	128	0.078	0.078	3.514*	3.310*
			-0.022	-0.024		
Kernel Matching	63	128	0.08	0.08	(-)*	3.466*
			(-)	-0.023		
Stratification Matching	63	128	0.084	0.084	(-)*	3.342*
			(-)	-0.025		

*Rule of thumb: should be greater than 2 to be significant

Results for the nearest neighbour matching before bootstrapping indicate that the effect of physical counting will result in a 0.088 increase in losses due to predation (and is significant). Bootstrapping will not change the estimated coefficient for the matching, but will change the standard error associated with the matching procedure from 0.027 to 0.025.

When the different methods of matching are applied the coefficients differ. With radius matching there will be a 0.078 increase; while the estimated coefficient for stratification matching is 0.08 and for kernel matching there is a 0.084 increase in predation losses.

More importantly the t-statistic estimated using any of the four matching methods are significant, therefore there is a difference for large antelope losses between physical counting and estimating, regardless of the matching method used.

4.6.2 SMALL ANTELOPE SPECIES

Regarding small antelope species, similar to large antelope species, it is necessary to test if there is a significant difference between physical counting and estimating antelope numbers. The results for the t-test are given in Table 4.10.

Table 4.10 T-test of small antelope species

Source	SS	Df	MSS		
Model	0.0070	1	0.0070	Prob > F	0.4912
Residual	2.9271	199	0.0147	R-squared	0.0024
Total	2.9342	200	0.0147	Adjusted R-square	-0.0026

Level of predation	Coeff	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Treatment	0.0126	0.0183	0.69	**0.491**	-0.0234	0.0487
Constant	0.1074	0.0104	10.33	0.000	0.0869	0.1279

The coefficient for treatment is positive (0.0126), however the coefficient is insignificant. Meaning that there is not a difference between physical counting and estimating. It can be hypothesized that the reason for small antelope species being insignificant is that bushbuck, reedbuck and rhebok are more difficult to see because they form smaller groups and are mostly active during night time according to Cillé (2003). Neither a Logit nor a Probit was fitted, because there is not a significant difference between physical counting and estimating antelope numbers.

4.6.3 SCARCE SPECIES/COLOUR VARIANTS

Firstly, it is important to determine if there is a difference between physical counting and estimating scarce/colour variant antelope and to estimate the propensity score that will be used for matching. The results for the t-test used to test for differences in physical counting and estimating are given in Table 4.11.

Table 4.11 T-test of scarce species/colour variants

Source	SS	Df	MSS		
Model	0.2192	1	0.2192	Prob > F	0.0000
Residual	2.3837	199	0.0120	R-squared	0.0842
Total	2.6029	200	0.0130	Adjusted R-square	0.0796

Level of predation	Coeff	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Treatment	0.0706	0.0165	4.28	**0.0000**	0.0381	0.1031
Constant	0.0097	0.0094	1.03	0.3020	-0.0088	0.0282

The coefficient for physical counting (treatment) is positive (0.0706) and also significant (0.0000) as for large antelope species. If antelope are physically counted, the level of predation will increase; two reasons may exist first, wildlife ranchers who physically count their wildlife have specific numbers, which is not the case with estimating and secondly, wildlife species are placed under more stress when physically counted which makes them more susceptible to predators.

A Logit or Probit model was fitted to determine the propensity score that will be used for matching. The region for common support on which the propensity score matching will be done is 0.0919 to 0.9467, which is an indication of the range of coefficients. There are five blocks for which the propensity scores are the same for the treatment and control groups.

The propensity scores determined for every observation is used to find a match for physical counting observations. Results for the matching procedures are given in Table 4.12.

Table 4.12 Average effect of Treatment on the Treated (ATT) estimation with matching methods (Scarce species/colour variants)

	Number of treatment groups	Number of control groups	ATT	ATT	T-Statistic	
			Before bootstrapping	After bootstrapping	Before bootstrapping	After bootstrapping
Nearest Neighbour	65	43	0.077	0.077	3.439*	3.293*
			-0.022	-0.023		
Radius Matching	60	129	0.074	0.074	3.102*	3.086*
			-0.024	-0.024		
Kernel Matching	65	129	0.075	0.075	(-)*	3.381*
			(-)	0.022		
Stratification Matching	61	133	0.073	0.073	3.133*	3.133*
			-0.023	-0.023		

*Rule of thumb: should be greater than 2 to be significant

Nearest neighbour matching before bootstrapping indicate that physical counting will lead to a 0.077 increase in the level of predation. Bootstrapping will only change the standard error, but will not affect the coefficient. The standard error will increase from 0.022 to 0.023 by bootstrapping the nearest neighbour method. There are a 0.074 increase with radius matching; the coefficient for radius matching will remain constant before and after bootstrapping with standard error remaining 0.024 after bootstrapping. With kernel matching there are a 0.075 increase in the level of predation, with a standard error of 0.022 after bootstrapping and a 0.073 increase with stratification matching with a standard error of 0.023 before and after bootstrapping. All the above mentioned coefficients are positive, indicating that physical counting increases the level of predation.

Yet again, it is important to note the t-statistic estimated using any of the four matching methods are significant for scarce species/colour variant antelope indicating a difference between physical counting and estimating.

4.7 WHAT DOES THIS MEAN FOR THE WILDLIFE RANCHER?

The Limpopo province has the largest variety of wildlife in South Africa, therefore the antelope species are divided into three groups, namely large species, small species and scarce species/colour variants. Of the more than 800 members of WRSA in the Limpopo province, a random sample of 201 was interviewed. The majority of the wildlife ranchers indicated that they estimate wildlife numbers followed by physical counting and number of wildlife available to hunt.

There are direct and indirect cost associated with predation. The direct cost are calculated per hectare, therefore each wildlife rancher can estimate his/her own losses on the wildlife ranch, by using the values given in **Appendix H** or what value they themselves use to value their wildlife. The indirect cost was estimated to be ZAR 26.15/ha; the total cost can be calculated by adding the direct and indirect costs. The direct cost in the Limpopo province can be ascribed to a few predators such as the leopard, caracal, black-back jackal and cheetah. By controlling these damage causing animals, the losses can be decreased. Therefore the factors that influences the occurrence and level predation was observed

Variables that influences the occurrence of predation is different than the variables that influence the level of predation and the variables also vary between the different wildlife groups. This results in this dissertation supports the findings of Van Niekerk (2010) and Badenhorst (2014). Only a few variables influences the occurrence of predation, meaning that there will always be some level of predation (losses) whether control methods are used or not, but the level of predation can be decreased by using certain non-lethal methods and methods assisting wildlife ranchers and lethal control methods. For instance the level of predation on small antelope species can be reduced by using non-lethal control methods or methods assisting wildlife ranchers such as cameras and lights and/or radios. The level of predation is affected differently in the three different groups, the level of predation is increase if black-back jackal is hunted by specialist hunters in the large antelope group and if the owner hunts caracal in the large and scarce species/colour variant antelope group, but the level of predation in decreased if the owner manages predation in the scarce species/colour variant antelope group.

The method of counting antelope also affects the level of predation on large and scarce/colour variant wildlife species. If the antelope of these two groups are physically counted the level of predation will increase, reasons being that the exact number is known, with estimating it is difficult to determine if only a few antelope is missing, also more stress is placed on wildlife if they are physically counted, making them more susceptible to predators. The method of counting does not influence wildlife in the small species wildlife group.

Even though losses will always be incurred by wildlife ranchers, it is important to implement some kind of management program or predation control method, whether it is non-lethal or lethal, to reduce the level of predation.

CHAPTER 5
Summary & Conclusion

5.1 INTRODUCTION

Prior to this study little information was available regarding predation in the South African wildlife industry. In general, wildlife ranchers do not have a good knowledge regarding the extent of predation losses on their properties; therefore, best management and control methods to mitigate the negative impact of predation are done rather haphazardly. The primary objective of this dissertation was to determine the economic implication of predation on the wildlife ranching industry by estimating the direct losses and quantifying the indirect losses, to investigate the factors that influence predation in the wildlife ranching industry of the Limpopo province and to determine if there is a marked on the level of predation between physical counting and estimating to determine wildlife numbers. The larger study included all nine provinces but the main focus of this dissertation was to explore in greater detail the situation in the Limpopo province.

5.2 MEETING THE OBJECTIVES OF THIS DISSERTATION

5.2.1 ESTIMATING THE DIRECT LOSSES AND QUANTIFYING THE INDIRECT LOSSES OF WILDLIFE DUE TO PREDATION

The direct cost of predation consists of all the direct losses of wildlife due to predation. The losses have been estimated per hectare (Table 5.1), because allocating a value to a specific wildlife species is difficult and can lead to over or underestimations. The five wildlife species in each of the three groups as defined, namely: large species, small species and scarce specie/colour variant antelope on which the most predation was reported in the Limpopo province were included in the calculations. The predator responsible for most losses in all three groups was leopard; followed by caracal. The black-back jackal is responsible for the third most losses of large and small antelope species and the cheetah is responsible for

Table 5.1 Total cost due to predation for a selection of antelope reported in this dissertation

	Average hectares Column 1	Average number of wildlife lost/ Hectare Column 2	Indirect cost/ hectare Column 3	Average wildlife prices Column 4	Total cost (ZAR) due to predation Column 5
			Large species		
Nyala	2 147.09	0.00416	26.15	24 165	252 898.00
Blue wildebeest	2 436.17	0.00220	26.15	14 495	119 735.32
Kudu	2 520.85	0.00399	26.15	33 923	384 713.90
Gemsbok	3 668.23	0.00292	26.15	8 496	154 316.27
Red hartebeest	2 249.36	0.00251	26.15	7 462	80 953.61
			Small species		
Impala	2 265.05	0.02162	26.15	8 643	462 345.77
Rhebuck	6 730.00	0.00084	26.15	10 750	176 931.70
Bush buck	1 754.44	0.00526	26.15	21 282	226 679.47
Reedbuck	1 150.83	0.00232	26.15	17 113	65 553.76
Blesbok	1 905.67	0.00927	2615	4 153	106 256.94
			Scarce species/colour variants		
Black impala	2 166.75	0.00110	26.15	684 761	1 669 474.59
Golden wildebeest	930.05	0.00243	26.15	1 230 486	2 796 977.48
King wildebeest	1 270.00	0.00354	26.15	1 230 486	5 553 939.16
Livingston eland	1 671.07	0.00411	26.15	282 430	1 968 599.50
Yellow blesbok	1 000.00	0.00600	26.15	949 330	5 713 240.00

the third most losses of scarce species/colour variant wildlife species, according to the wildlife ranchers.

The indirect cost includes the cost of using non-lethal methods and methods assisting wildlife ranchers and lethal methods to prevent and control predation. Non-lethal methods and assisting methods includes cage traps, guarding animals and the use of cameras, lights and/or radios. Lethal methods include poison, foothold traps and shooting.

The total indirect cost of predation was also caculated to be ZAR 26.15/ha in the Limpopo province. The total cost (Table 5.1) is a summary of the wildlife species included in the dissertation. In Table 5.1, Column 1 illustrates the average hectare of the wildlife ranchers who participated in the dissertation for the specific species. Column 2 illustrates the average number of each of these species lost/ha. The indirect cost for the dissertation was estimated at ZAR 26.15/ha (Column 3). Column 4 indicates the average price during 2014. The total cost was calculated by multiplying the average hectares (Column 1) with the average number lost/ha (Column 2) with the average 2014 price (Column 4) and adding the indirect cost/ha (Column 3) multiplied with the average hectare (Column 1).

Each wildlife rancher can now use this value to estimate his/her own total cost due to predation by adding the direct and indirect costs (Table 5.1).

The total indirect cost/ha calculated for the Limpopo province (ZAR 26.15) is much higher than the total indirect cost for predation in the large livestock industry in the Northwest province. The total cost of non-lethal and lethal methods are ZAR 1 683 600, when this value is calculated per ha, the total indirect cost per ha due to predation in the large livestock industry is ZAR 3.08 (Badenhorst, 2014).

This study was the first that focussed on the economic implication of predation on wildlife. There is still some speculation regarding predation losses. Wildlife ranchers can now determine the predation losses on their own properties and make decisions regarding management practices to mitigate the impact of predation.

The results obtained by calculating losses for the defined three scenarios provided an indication of the extent of the losses on wildlife ranches in the Limpopo province. Calculating the total cost for the entire wildlife sector may lead to over or underestimations; therefore the total cost were calculated/ha. This baseline value enables wildlife ranchers to calculate their own predation losses for different scenarios: for example, a wildlife rancher who keeps nyalas on 5 000 ha can calculate his/her estimated total cost to be ZAR 638 215/year. Similarly, a wildlife rancher who keeps blesbok on 12 000 ha can incur a total cost of ZAR 774 783/year and a wildlife rancher who keeps black impala and Livingston eland on 6 000 ha can calculate his/her total cost to be ZAR 12 010 977/year. It was concluded from these three scenarios that the losses due to predation, as caculated in all three groups, were large; this is in line with the hypothesis.

The calculation of the total cost of predation in the wildlife ranching industry followed on those by Van Niekerk (2010) and Badenhorst (2014) and concludes the economic studies done at the UFS on predation in the livestock and wildlife industries in South Africa. In the first two studies Van Niekerk (2010) calculated the economic losses in the small livestock (sheep and goat) industry and Badenhorst (2014) calculated the economic losses in the large (cattle) livestock industry.

5.2.2 FACTORS THAT INFLUENCE THE OCCURRENCE AND LEVEL OF PREDATION

This secondary objective provided an indication of the variables contributing to the occurrence and level of predation of each wildlife group, defined as large species, small species and scarce species/colour variant antelope, to determine what management practices should be used.

LARGE ANTELOPE SPECIES

Only four variables were significantly associated with the probability of occurrence and seven variables were significantly associated with the probability of changing the level of predation. There were no predation control methods that had a significant effect on the occurrence of predation. Electric fences has an increasing effect on the level of predation which is the opposite effect of what was hypothesised. Black-back jackal hunted by specialist hunters and caracal hunted by the owner both have an increasing effect on the level of predation.

SMALL ANTELOPE SPECIES

There were four variables that significantly related to the probability of the occurrence and three variables that were significantly associated with the level of predation. The overall use of cage traps have an increasing effect on the occurrence of predation, as well as on the level of predation. The use of lights and/or radios and cameras will reduce the level of predation on small antelope species.

SCARCE SPECIES/COLOUR VARIANT ANTELOPE

Six variables had a significant effect on the occurrence of predation and three variables had a significant effect on the level of predation. Black-back jackal, caracal and wild dogs are seen as priority predators by the wildlife ranchers that affect the occurrence of predation and if the owner manages predation the level of predation will decrease.

The results support the findings of Van Niekerk (2010) and Badenhorst (2014) regarding different variables that affects the occurrence and level of predation. The vacuum effect described by Snow (2006), Badenhorst (2014) and Minnie, Gaylord and Kerley (2015) also has an effect on the wildlife industry. The vacuum effect may be an important reason why the variables affecting the occurrence and the variables affecting the level of predation are different. The variables affecting the three different groups of wildlife species also vary.

The Probit and Truncated models indicated that different variables affect the occurrence and level of predation. The coefficients of the Double hurdle model indicated if the variables affecting the occurrence and level of predation increases or decreases predation. It was observed that non-lethal control methods, such as lights and/radios and cameras reduce the level of predation; whereas most lethal methods will increase the level of predation. It is concluded is that management and control methods should be used in accordance with the specific species on the wildlife ranch.

5.2.3 PROPENSITY SCORE MATCHING

According to propensity score matching the method of counting wildlife numbers also influences the level of predation. It was concluded that if wildlife is physically counted the level of predation on large and scarce species/colour variant antelope will increase. Two possible reasons may be the cause: firstly, when wildlife is physically counted the exact numbers are known, which is not the case if wildlife numbers are estimated, secondly, wildlife is put under more stress making them more susceptible to predators. However, the method of counting do not have a marked influence on the level on predation on small antelope species, this can be ascribed to rhebok, reedbuck and bushbuck being more active in the night and are found in smaller groups making them more difficult to spot for counting.

Results obtained from the Northwest and Free State provinces of the factors influencing the occurrence and level of predation are presented in **Appendices A** and **B**; however, propensity score matching could not been done for these two Provinces, because too few wildlife ranchers chose physical counting as a method of counting wildlife.

The descriptive statistics for the Eastern Cape, Kwa-Zulu Natal, Mpumalanga, Northern Cape and Western cape are given in **Appendices** (**C-G**). The WRSA members who were contacted in the Gauteng province are ranching with wildlife in the Limpopo province.

5.3 LIMITATIONS OF THE STUDY

The scale of predation is already very large in South Africa, therefore the use of models to determine problems are not important anymore; sustainable management practices need to be employed to reduce the level of predation. Only a few wildlife ranchers chose physical counting as a method of determining wildlife numbers; therefore the study made used of pooled data to increase the degrees of freedom in the estimations, by splitting the data in two and then doing the Cragg's test again, may influence the results obtained.

Data collection give rise to other problems. Firstly, the data were collected from only a portion of the WRSA members, which means the data is a portion of a proportion. Secondly, wildlife ranchers provided the information regarding predation, meaning an expression of their opinions and this may skew the results.

The propensity score matching was used only to test whether the level of predation was different between physical counting and estimating, the study did not aim to determine the factors that contribute to wildlife ranchers using physical counting over estimating.

5.4 RECOMMENDATIONS

Predation is an old problem in the small and large livestock industries and this dissertation clearly confirmed that challenges of predation are also impacting negatively on the wildlife industry. The dissertation suggested that losses due to predation will always occur, but the level of predation can be reduced. Based on the results of this dissertation it is recommended that wildlife ranchers use predation control methods; it is suggested that non-lethal control methods are preferred, but the use of lethal control methods may be used judiciously.

Further research is needed to determine the factors that give rise to physical counting of animals rather than merely estimating wildlife numbers. Factors that influence a wildlife rancher’s decision to physically count rather than estimating wildlife numbers.

Wildlife ranchers need to take action themselves together with livestock producer organizations (preferably as a coordinated front in the PMF) and organised agriculture. Wildlife ranchers need to work together with the same end goal in mind, namely to reduce the level of predation on their wildlife ranches.

This dissertation is the ideal set of guide lines for wildlife ranchers, producer organizations and government to formulate public statements and propose relevant recommendations.

References

ABSA, 2015. Landbouvooruitskouing.

Abstract of Agricultural Statistics, 2015. Department of Agriculture, Forestry & Fisheries. South Africa.

African Large Predator Research Unit (ALPRU), 2013. http://natagri.ufs.ac.za/content.aspx?DCode=100&DivCode=D029 [25 August 2015].

Andelt, W.F., 2004. Use of livestock guarding animals to reduce predation on livestock. Sheep & Goat Research Journal 19: 72-74.

Arnold, M.B., 2001. Wildlife integration for livelihood diversification project (working paper 6). Department for International Development.

Avenant, N., De Waal, H.O. & Combrinck, W., 2006. The Canis-Caracal Programme: a holistic approach. In: Daly, B., Davies-Mostert, H., Davies-Mostert, W., Evans, S., Friedmann, Y., King, N., Snow, T. & Stadler, H. (eds.). Prevention is the cure. Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa. (pp. 21-25). Endangered Wildlife Trust, Johannesburg.

Avenant, N.L. & Du Plessis, J.J., 2008. Sustainable small stock farming & ecosystem conservation in Southern Africa: a role for small mammals? *Mammalian Biology 72: 258-263.*

Avenant, N.L. & Nel, J.A.J., 1998. Home-range use, activity & density of caracal in relation to prey density. *African Journal of Ecology 36: 347-359.*

Avenant, N.L. & Nel, J.A.J., 2002. Among habitat variation in prey availability & use by caracal Felis caracal. *Mammalian Biology 67: 18-33.*

Badenhorst, C.G., 2014. The economic cost of large stock predation in the North West Province of South Africa. M.Sc. (Agric.) dissertation. University of the Free State, Bloemfontein, South Africa.

Bailey, T.N., 1993. The African leopard: ecology & behaviour of a solitary felid. New York: Columbia University Press.

Balme, G.A., Batchelor, A., De Woronin Britz, N., Semour, G., Grover, M., Hes, L., MacDonald, D.W. & Hunter, L.T.B., 2012. Reproductive success of female leopards Panthera pardus: the importance of top-down processes. *Mammal Review: 1-15.*

Barlett, J.E., Kotrlik, J.W. & Higgins, C.C., 2001. Organizational Research: Determining appropriate sample size in survey research. *Information Technology, Learning, & Performance Journal 19(1): 43-49.*

Becker, S.O. & Ichino, A., 2002. Estimation of average treatment based on propensity scores. *The Stata Journal 2(4): 358-377.*

Beinart, W., 1998. The night of the jackal: Sheep, pastures & predators in the Cape. *Oxford Journal 158: 172-206.*

Bergman, D.L., De Waal, H.O., Avenant, N.L., Bodenchuk, M.J., Marlow, M.C. & Dale, D.L., 2013. The need to address black-backed jackal & caracal predation in South Africa. Proceedings 15th Wildlife Damage Management Conference, 25-28 March 2013, Clemson, South Carolina (J.B. Armstrong, G.R. Gallagher, Eds.). (pp 86-94)

Bernard, R.T.F. & Stuart, C.T., 1987. Reproduction of the caracal Felis caracal from the Cape Province of South Africa. *South African Journal of Zoology 22(3): 177-182.*

Bertram, B.C.B., 1999. Leopard. In the encyclopedia of mammals: 44-48. Macdonald, D.W. (ed.). Oxford: Andrameda Oxford Limited.

Bezuidenhout, R., 2014. Auction turnover breaks the billion-rand barrier. [Online]. Retrieved from: http://www.farmersweekly.co.za/article.aspx?id=52740&h=Auction-turnover-breaks-the-billion-rand-barrier [4 February 2015].

Bjorge, R.R. & Gunson, J.R., 1985. Evaluation of wolf control to reduce cattle predation in Alberta. *Journal of Range Management 38(6): 483-487.*

Bluman, A.G., 2004. Elementary Statistics: a step by step approach. (5th.). New York: McGraw Hill.

Bodenchuk, M.J., Mason, J.R. & Pitt, W.C., 2000. Economics of predation management inrelation to agriculture, wildlife, & human health & safety. University of Nebraska.

Bothma, J. du P., 1984. Aspects of the ecology & the behaviour of the leopard Panthera pardus in the Kalahari desert. *Koedoe:* 259-279.

Bothma, J du P., 2012. Literature review of the ecology & control of the Black-back Jackal& Caracal in South Africa. B.Sc & M.Sc (University of Pretoria) PhD (Texas A & M University) *Science Nature. July 2012.*

Brassine, M.C., 2011. The diet & ecological role of Black-backed Jackals, Canis Mesomelas, in two conservation areas in the Eastern Cape Province, South Africa. (M.Sc. Thesis). Rhodes University, South Africa.

Breitenmoser, U., Breitenmoser-Würsten, C.H., Okarma, H., Kaphegyi, T., Kaphegyi-Wallman, U. & Müller, U.M., 1998. Action plan for the conservation of the European lynx in Europe (Lynx lynx). Nature & Environment 112, Council of Europe, Strasbourg.

Bromley, C. & Gese, E.M., 2001. Surgical sterilization as a method of reducing coyote predation on domestic sheep. *Journal of Wildlife Management 65(3): 516-517.*

Bronner, G.N., Hoffmann, M., Taylor, P.J., Chimimba, C.T., Best, P.B., Matthee, C.A. & Robinson, T.J., 2003. A revised systematic checklist of the extant mammals of the southern African subregion. *Durban Museum Novitates* 28: 56-106.

Caliendo, M. & Kopeinig, S., 2005. Some practical guidance for the Implementation of Propensity Score Matching. *The Institute for the study of Labor 1588: 1-24.*

Cillé, B., 2003. Foto-sakgids tot soogdiere van suider-Afrika. Sunbird publishers, Kaapstad, Suid-Afrika.

Cilliers, D., 2006. The de Wildt cheetah & wildlife trust: Wild cheetah project assisting with human-predator conflict resolution. In: Daly, B., Davies-Mostert, H., Davies-Mostert, W., Evans, S., Friedmann, Y., King, N., Snow, T.& Stadler, H. (eds.). Prevention is the cure. Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa. (pp. 51-52). Endangered Wildlife Trust, Johannesburg.

Cloete, P.C, Van Der Merwe, P. & Saayman, M., 2015. Game ranch profitability in South Africa, 2015 ed. Published by ABSA.

Conover, M., 2001. Effect of hunting & trapping on wildlife damage. *Wildlife Society Bulletin* 29: 521-532.

Crawford, R.M.M., 2000. Ecological hazards of oceanic environments. *New Phytology 147: 257-281.*

De Vos, A.S., Strydom, H., Fouche, C.B. & Delport, C.L.S., 2002. Research at Grass Roots: For the Social Sciences & Human Service Professions, (Eds) 2nd Edition. Van Schaik Publishers.

De Waal, H.O., 1990. Animal production from native pasture (veld) in the Free State Region -

a perspective of the grazing ruminant. *South African Journal of Animal Science* 20:1-9.

De Waal, H.O., 2007. Staan landwyd saam teen probleemdiere. *Landbouweekblad* 10 August 2007: 26-27.

De Waal, H.O., 2009a. Recent advances in coordinated predator management in South Africa. Merino SA Focus 2009: 44-46.

De Waal, H.O., 2009b. Predator debate needs level heads. Farmers Weekly 3 July 2009: 6.

De Waal, H.O., 2012. Koördineer tog! Landbouweekblad 27 Januarie 2012: 32-34.

De Waal, H.O., 2015. Predator Relationships. Wildlife Ranching Issue 1 2015: 213-217.

Dreyer, H.V.A. & Nel, J.A.J., 1990. Feeding site selection by black-backed jackals on the Namib dessert coast. Journal of Arid Environments 19(2).

Dry, G.C., 2011. Commercial wildlife ranching's contribution to a resource efficient, low carbon, pro-employment green economy. 7th International Wildlife Ranching Symposium, Kimberley, South Africa, 9-13 October 2011.

Dry, G.C., 2015. Breeding practices & objectives in the wildlife industry. Wildlife Ranching Information Day, Windhoek, Namibia, 14 November 2015.

Du Plessis, J.J., 2013. Towards a sustainable management strategy for *Canis mesomelas* & *Caracal caracal* on rangeland. Ph.D. thesis, University of the Free State, Bloemfontein.

Du Plessis, J.J., Avenant, N.L. & De Waal, H.O., 2015. Quality and quantity of the scientific information available on black-back-jackals and caracals: contributing to human-predator conflict management? African Journal of Wildlife Research 45(2): 138-157.

Du Toit, C.J.L., Meissner, H.H. & Van Niekerk, W.A., 2013. Direct greenhouse gas emissions of the game industry in South Africa. *South African Journal of Animal Science* 43(3): 376-393.

Erasmus, D., 2012. 21st century predator control. [Online]. Retrieved from: http://www.farmersweekly.co.za/article.aspx?id=16604&h=21st-century-predator-control [16 March 2015].

Fairall, N., 1968. The reproductive seasons of some mammals in the Kruger National Park. *Zoologica Africana 3:189-210.*

Ferguson, J.W.H., Nel, J.A.J & De Wet, M.J., 1983. Social organization & movement patternsof black-backed jackals Canis Mesomelas in South Africa. *Journal of Zoology, London 199: 487-02.*

Ferreira, N.A., 1988. Sekere aspekte van die ekologie en die beheer van die rooikat (Felis caracal) in die Oranje-Vrystaat. Unpublished report, Orange Free State Provincial Adminstration, Directorate Environmental & Nature Conservation, Bloemfontein.

Geweke, J.F. & Singleton, K.J., 1980. Interpreting the likelihood ratio statistic in factor models when sampling size is small. *Journal of the American Statistical Association 75: 369.*

Graham, K., Beckerman, A.P. & Thirgood, S., 2005. Human-predator-prey conflicts: ecological correlates, prey losses & patterns of management. *Biological Conservation 122: 159-171.*

Green, J.S., Woodruff, R.A. & Tueller, T.T., 1984. Livestock-guarding dogs for predator control: Costs, benefits & practicality. *Wildlife Society Bulletin 12: 44-50.*

Greentree, C., Saunders, G., McLeod, L. & Hone, J., 2000. Lamb Predation & Fox Control in South-Eastern Australia. *Journal of Applied Ecology 37(6): 935-943.*

Greyling, A., 2006. Current regulatory system governing damage-causing/Problem animal control in South Africa. In: B.Daly, W. Davies-Mostert, S.Evans, T. Friedmann, N. King, T. Snow, & Stadler, H. (eds.). Prevention is the cure. Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa.(p 65).Endangered Wildlife Trust, Johannesburg.

Gunter, Q., 2008. A critical evaluation of historical data on two damage causing predators, *Canis mesomelas* and *Caracal caracal*. M.Sc. dissertation, University of the Free State, Bloemfontein, South Africa.

Hashim, Y.A., 2010. Determining sufficiency of sample size in management survey research activities. *International Journal of Organisational Management & Entrepreneurship Development 6(1): 119-130.*

Heard, H.W. & Stephenson, A., 1987. Electrification of a fence to control the movement of black-backed jackals. *South African Journal of Wildlife Research 17(1): 20-24.*

Hecht, A. & Nickerson, P.R., 1999. The need for predator management in conservation of some vulnerable species. *Endangered Species update 16: 114-118.*

Holekamp, K.E. & Smale, L., 1990. Provisioning & food sharing by lactating spotted hyenas, Crocuta crocuta (Mammalia: Hyaenidae) *Ethology 86: 191-202.*

Holton, E.H. & Burnett, M.B., 1997. Qualitative research methods. In Swanson, R.A. & E.F. Holton (Eds.), Human resource development research handbook: Linking research & practice. San Francisco: Berrett-Koehler Publishers.

Hurrell, J.W., 1995. Decadal Trends in the North Atlantic Oscillation. Regional Temperatures & precipitation. *Science 269(5224): 676-679.*

Kamler, J.F., Klare, U. & Macdonald, D.W., 2012. Seasonal diet & prey selection of black back jackals on a small-livestock farm in South Africa. *African Journal of Ecology 50: 299-307.*

Katchova, A.L. & Miranda, M.J., 2004. Two-step econometric estimation of farm characteristics affecting marketing contract decisions. American Agricultural Economics Association.

Katchova, A., 2013. Propensity Score Matching. https://www.youtube.com/watch?v=-HVGe0LKLo [20 November 2015)

Kaunda, S.K.K., 2002. Activity patterns of black-backed jackals at Mokolodi Nature Reserve, Botswana. *South African Journal of Wildlife Research 30(4): 157-162.*

Knowlton, F.F., Gese, E.M. & Jaeger, M.M., 1999. Coyote depredation control: An interface between biology & management. *Journal of Range Management 52(5): 398.*

Kralik, S., 1967. Breeding of the caracal lynx Felis caracal. *International Zoo Yearbook 7: 132.*

Krejcie, R.V. & Morgan, D.W., 1970. Determining sample size for research activities. *Educational & Psychological Measurement 30: 607-610.*

Kruuk, H., 1972. The spotted hyena: a study of predation & social behaviour. Chicago: University of Chicago Press.

Lamprecht, J., 1978a. On diet, foraging behaviour & interspecific food competition of jackalsin the Serengeti National Park, East Africa. Zeitschrift für *Saugetierkunde. 43: 210-223.*

Lamprecht, J., 1978b. The relationship between food competition & foraging group size in some larger carnivores: a hypothesis. Zeitschrift für *Tierpsychologie. 46: 337-343.*

Lance, P., Guilkey, D., Hattori, A. & Angeles, G., 2014. How do we know if a program made adifference? A guide to statistical methods for program impact evaluation. Chapel Hill, North Carolina: Measure evaluation.

Landa, A., Fudvangen, K., Swenson, J.E. & Roskaft, E., 1999. Factors associated with wolverineGulogulo predation on domestic sheep. *Journal of Applied Ecology 36(6): 963-973.*

Laurenson, M.K., Caro, T.M., & Borner, M., 1992. Female cheetah reproduction. *National Geographic Research & Exploration 8(1): 64-75.*

Lechner, M., 2002. Some practical issues in the evaluation of heterogenous labour market programmes by matching methods. *Journal of the Royal Statistical Society 165: 59-82.*

Lehohla, P., 2014. National Accounts: Tourism satellite account for South Africa, final 2010 and provisional 2011 & 2012. Pretoria: Statistics South Africa, March, 2014.

Lin, T. & Schmidt, P., 1982. A test of the Tobit specification against an alternative suggested by Cragg. *The Review of Economics and Statistics* 66(1): 174-177.

Link, R., 2004. Living with wildlife. [Online] Retrieved from: http://wdfw.wa.gov/living/coyotes.html [23 January 2015].

McAdoo, J.K. & Glimp, H.A., 2000. Sheep Management as a Deterrent to Predation. *Rangelands 22(2): 21-24.*

Mclnerney, J.P., Howe, K.S. & Scheepers, J.A., 1992. A framework for the economic analysis of disease in farm livestock. *Preventive Veterinary Medicine 13: 137-154.*

Mills, M.G.L. & Harvey, M., 2001. African predators. Cape Town: Struik Publishers.

Minnie, L. Gaylord, A. & Kerley, G.I.H., 2015. Compensatory life-history responses of a mesopredator may undermine carnivore management efforts. *Journal of Applied Ecology (9pp)* doi:10.1111/1365-2664.12581.

Mishra, C., 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions & conservation prospects. *Environmental Conservation 24(4): 338-343.*

Mmbengeni, M.E. & Mokoko, M.S., 2002. Provincial report on education & training for agriculture & rural development in Limpopo Province. Limpopo Department of Agiculture 4-12.

Moberly, R.L., 2002. The cost of fox predation to agriculture in Britain. (Ph.D. Thesis). Environment Department, University of York.

Myers, N., 1975. The cheetah Acinonyx jubatus in Africa-IUCN Monograph No.4.IUCN, Morges, Switzerland, 88.

Nass, R.D., Lynch, G. & Theade, J., 1984. Circumstances associated with predation rates on sheep & goats. *Journal of Range Management 37: 423-426.*

National Department of Agriculture (NDA) 2012. Estimated livestock numbers and also the estimated hectares of grazing land. [Online]. Retrieved from: http://www.daff.gov.za/ [17 July 2015].

Nattrass, N. & Conradie, B., 2013. Jackal Narratives and predator control in the Karoo, South Africa. Centre for social science research, working paper no. 324.

Neuman, W., 2004. Basics of social research: Qualitative and quantitative approaches. Boston: Pearson Education, Inc.

Nowell, K. & Jackson, P., 1996. Wild cats: Status survey & conservation action plan. Burlington Press, Cambridge.

O'Farrell, R., 2015. Advantages & disadvantages of cost benefit analysis. [Online]. Retrieved from: http://smallbusiness.chron.com/advantages-disadvantages-cost-benefit-analysis-10676.html [29 January 2015].

Oli, M.K., Taylor, I.R. & Rogers, M.E., 1994. Snow leopard *Panthera uncia* predation of livestock- an assessment of local perceptions in the Annapurna Conservation area, Nepal. *Biological Conservation 68(1): 63-68.*

Olken, F. & Rotem, D., 1986. Simple random sampling from relational databases. Proceedings of the twelfth international conference on very large databases.

Otte, M.J. & Chilanda, P., 2001. Animal health economics. Livestock information, Sector.

Owen-Smith, N. & Mills, M.G.L., 2008. Predator-prey size relationship in an African large-mammal food web. *Journal of Animal Ecology 77: 173-183.*

Palmer, R. & Fairall, N., 1988. Caracal & African wild cat diet in the Karoo National Park & the implications there of for hyrax. *South African Journal of Wildlife Research 18: 30-34.*

Peers, I., 1996. Statistical analysis for education & psychology researchers. Bristol, PA: Falmer Press.

Philander, S.G., 1990. El Niño, La Niña & the Southern Oscillation, Academic Press, New York.

Pickover, M., 2005. Animal rights in South Africa. Cape Town: Double Storey Books.

Proclamation by the member of the executive council for the department of economic development & environmental affairs, 2011. *Provincial Gazette Extraordinary 2503(3): 7.*

Rasmussen, G.S.A., 1999. Livestock predation by the pointed hunting dog *Lycaon pictus* in a cattle ranching region of Zimbabwe: a case study. *Biological Conservation 88: 133-139.*

Reyneke, J., 2015. Wildsyfers onder die vergrootglas. Wildsplaas 1(2): 1-5.

Rosenbaum, P.R. & Rubin, D.B., 1983. The central role of the propensity score inobservational studies for causal effects. *Biometrika 70(1): 41–55.*

Seaberg, J.R., 1988. Utilizing sampling procedures. *Social work research & evaluation. 3.*

Sekulic, R., 1978. Seasonality of reproduction in the sable antelope. *Ecological African Wildlife Journal 16: 177.*

Shelton, M., 2004. Predation & livestock production perspective & overview. *Sheep & Goat Research Journal* 19: 2-5.

Shivik J.A., 2004. Wildlife Damage Management, Internet Centre for Sheep & Goat Research Journal. USDA, Wildlife Services, National Wildlife Research Centre & Utah State University.

Shwiff, S.A. & Bodenchuk, M.J., 2004. Direct, spillover, & intangible benefits of predation management. *Sheep & Goat Research Journal 19: 50-52.*

Shwiff, S.A. & Merrell, R.J., 2004. Coyote Predation Management: An Economic Analysis of Increased Antelope Recruitment & Cattle Production in South Central Wyoming. *Sheep & Goat Research Journal 19: 29-33.*

Skead, D.M., 1973. Incidence of culling in the black-backed jackal. *Journal of the Southern African Wildlife Management Association 3: 28-29.*

Skinner, J.D. & Chimimba, C.T., 2005. The mammals of the southern African subregion, Cape Town, South Africa: Cambridge 2010 Press.

Snow, T., 2006. Advantages and disadvantages of various control methods. Southern Africa, Endangered Wildlife Trust, Johannesburg.

South African Government, 2014. http://www.gov.za/wildlife-auction-generates-millions revenue [14 October 2015].

South African year book 2013/14. Department of Communication.[Online]. Retrieved from: http://www.gcis.gov.za/sites/www.gcis.gov.za/files/docs/resourcecentre/yearbook/2013-4Agriculture.pdf [4 February 2015].

Stadler, H., 2006. Historical perspective on the development of problem animal management in the Cape Province. In: Daly, B., Davies-Mostert, H., Davies-Mostert, W., Evans, S., Friedmann, Y., King, N., Snow, T. & Stadler, H. (eds.). Prevention is the cure. Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa. (pp. 11-16). Endangered Wildlife Trust, Johannesburg.

Stahl, P., Vandel, J.M., Ruette, S., Coat, L., Coat, Y. & Balestra, L., 2002. Factors affecting lynx predation on sheep in the French Jura. *Journal of Applied Ecology 39: 204-216.*

Stander, P.E., 1991. Aspects of the ecology & scientific management of large carnivores insub-Saharan Africa- M.Sc. Thesis, University of Cambridge, 118.

Stats SA. Census 2011.

Stoddart, D.M., 1979. Feeding behaviour in Caracal Felis Caracal. *Journal of Zoology, London 189: 523-557.*

Stoker D.J., 1985. Die 1985-steekproefbevolkingsopname in die Republiek van Transkei. *Raad van Geesteswetenskaplike Navorsing, Pretoria.*

Strauss, A.J., 2009. The impact of predation on a sheep enterprise in the Free State region. M.Sc. (Agric.) dissertation. University of the Free State, Bloemfontein.

Stuart, C.T. & Stuart, T., 2000. Field guide to the larger mammals of Africa. Cape Town: Struik Publishers.

Taylor, D.T., Rashford, B.S., Coupal, R.H. & Foulke, T., 2009. An economic analysis of predator management in Wyoming. Wyoming animal damage management board, Wyoming department of agriculture 40-43.

Taylor, R.J., 1984. Predation. Chapman & Hall, New York, New York, USA.

Thorn, M., Green, M., Dalerum, F., Bateman, P.W. & Scott, D.M., 2012. What drives human carnivore conflict in the North West Province of South Africa? *Biological conservation 150: 23-32.*

Treves, A., 2009. Hunting for large carnivore conservation. *Journal of Applied Ecology 46(6): 1350-1356.*

Van Der Merwe, P. & Saayman, M., 2002. Managing wildlife farms from a tourism perspective. Potchefstroom: Leisure C Publications.

Van Der Merwe, P. & Saayman, M., 2003. Determining the economic value of wildlife farmtourism. *Koedoe 46(2): 103-112.*

Van der Merwe, P., Saayman, M. & Krugell, W., 2004. Factors that determine the price of game. *Koedoe* 47(2): 105-113.

Van Deventer, J., 2008. CapeNature's reasons for the legislation. [Online]. Retrieved from:http://www.jarcal.com [16 February].

Van Niekerk, H.N., 2010. The cost of predation on small livestock in South Africa by medium-sized predators. M.Sc. (Agric.) dissertation. University of the Free State, Bloemfontein.

White, P.J., Garrott, R.A., Cherry, S., Watson, F.G.R., Gower, C.N., Becker, M.S. & Meredith, E., 2009. Changes in elk resource selection & distribution with the reestablishment of wolf predation risk. *The ecology of large mammals in central Yellowstone.*

Wielgus, R.B. & Peebles, K.A., 2014. Effects of wolf mortality on livestock depredations. *PlosOne 9(12):7-10.*

Wyman, J., 1967. The jackal of the Serengeti. *Animals 10: 79-83.*

Yom-Tov, Y., Ashkenazi, S. & Viner, O., 1995. Cattle predation by the golden jackal Canis aureus in the Golan Heights, Israel. *Biological Conservation 73: 19-22.*

Zuckerman, S., 1953. The breeding season of mammals in captivity. *Proceedings of Zoology. Society, London 122: 827-950.*

Appendix A: Northwest

Table A1: Number of wildlife ranchers surveyed and hectares utilised in the Northwest province

	Surveyed	Northwest province	Percentage
Wildlife ranchers	61	264	23.11
Wildlife ranches (ha)	140 922	6 738 014	2.00

Table A2: Options chosen by wildlife ranchers to establish the numbers of wildlife in the Northwest province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	5	0	56	0
Percentage of province	8.20	0	91.80	0

Table A3: Three defined groups of antelope species

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Kudu	*Tragelaphus strepsiceros*	Impala	*Aepyceros melampus*	Sable	*Hippotragus niger*
Nyala	*Tragelaphus angasii*	Blesbok	*Damaliscus pygargus*	Black impala	*Aepyceros melampus*
Blue wildebeest	*Connochaetes taurinus*	Bushbuck	*Tragelaphus scriptus*	Roan	*Hippotragus equinus*
Gemsbok	*Oryx gazelle*	Springbok	*Antidorcas marsupialis*	Copper springbok	*Antidorcas marsupialis*
Red hartebeest	*Alcelaphus buselaphus*	Reedbuck	*Redunca arundinum*	Tsessebe	*Damaliscus lunatus*

Table A4: A summary of average hectare and average losses of antelope calculated for the Northwest province

	Sample Size Column 1	Wildlife ranchers owning species Column 2	% Wildlife ranchers owning Species Column 3	Number of individual animals lost due to predation Column 4	Average ha Column 5	Average number of each species lost/wildlife rancher Column 6	Average number lost/ha Column 7
Large species							
Kudu	61	30	49.18	153	2 814.21	5.10	0.0018
Nyala	61	30	49.18	184	1 182.75	6.13	0.0052
Blue wildebeest	61	6	9.84	14	4 006.83	2.33	0.0006
Gemsbok	61	10	16.39	222	3 853.00	22.20	0.0058
Red hartebeest	61	6	9.84	39	1 317.83	6.50	0.0049
Small species							
Impala	61	43	70.49	772	2 413.95	17.95	0.0074
Blesbok	61	30	49.18	345	3 054.35	11.50	0.0038
Bushbuck	61	2	3.28	15	3 300.00	7.50	0.0023
Springbok	61	26	42.62	537	2 720.75	20.65	0.0076
Reedbuck	61	2	3.28	18	1 400.00	9.00	0.0064
Scarce species/colour variants							
Sables	61	18	29.51	27	2 623.56	1.50	0.0006
Black impala	61	9	14.75	11	2082.63	1.22	0.0006
Roan	61	6	9.84	13	2 446.67	2.17	0.0009
Copper springbok	61	7	11.48	38	2 066.67	5.43	0.0026
Tsessebe	61	3	4.92	10	2 050.00	3.33	0.0016

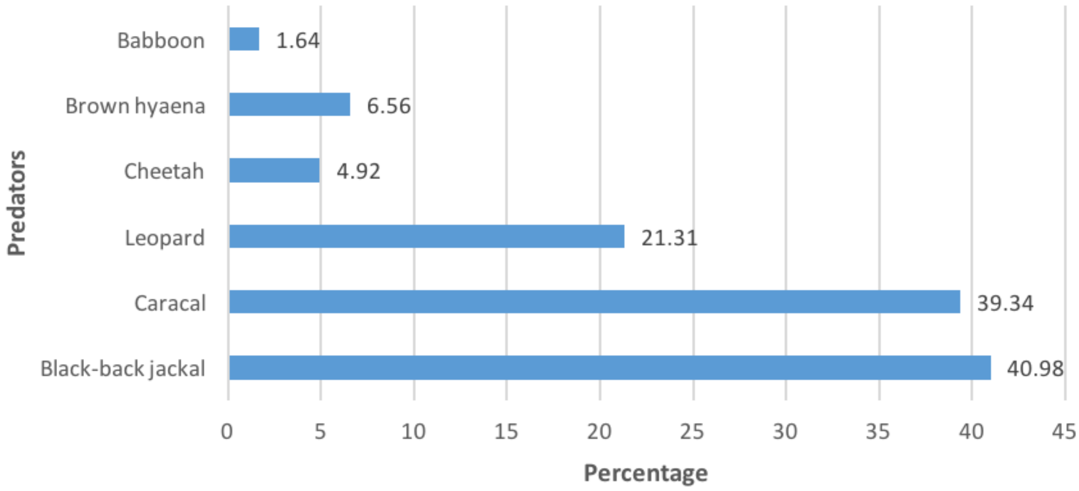

Figure A1: **Predators responsible for losses on large antelope species on wildlife ranches of WRSA members**

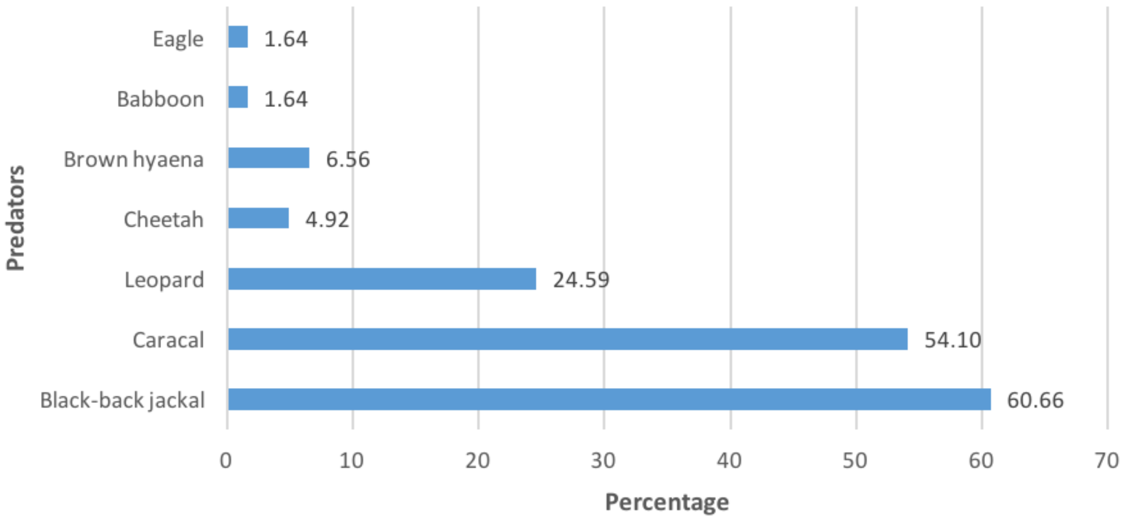

Figure A2: **Predators responsible for losses on small antelope species on wildlife ranches of WRSA members**

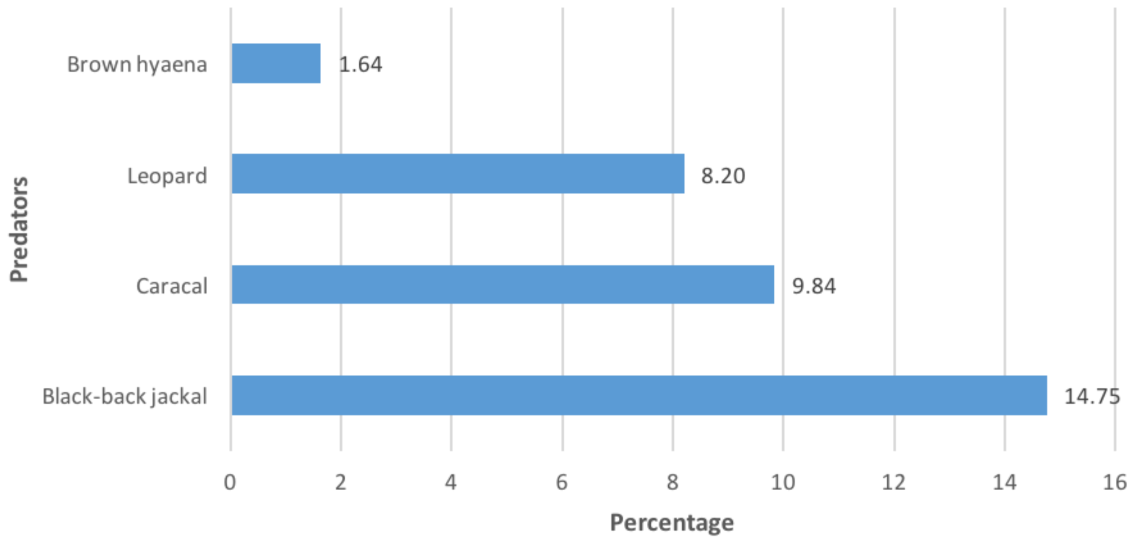

Figure A3: **Predators responsible for losses on scarce species/colour variant antelope on wildlife ranches of WRSA members**

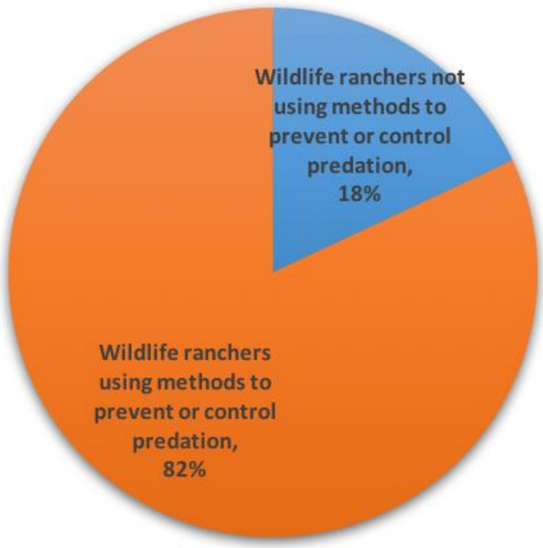

Figure A4: **Percentage of WRSA members using predation management methods in the Northwest province**

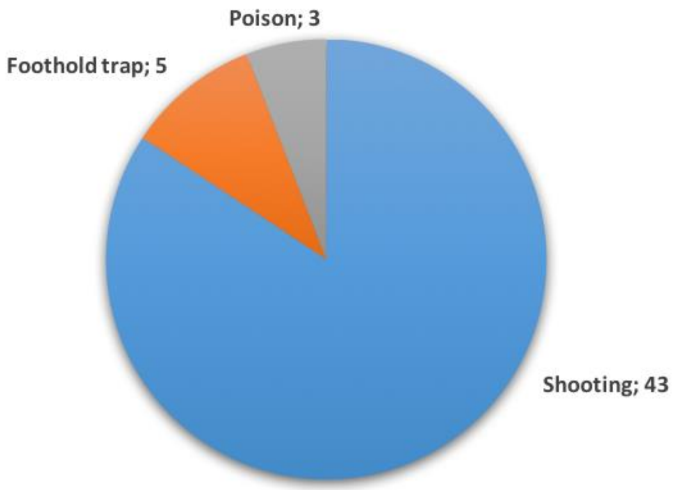

Figure A5: **Number of WRSA members using lethal control methods to control predators in the Northwest province**

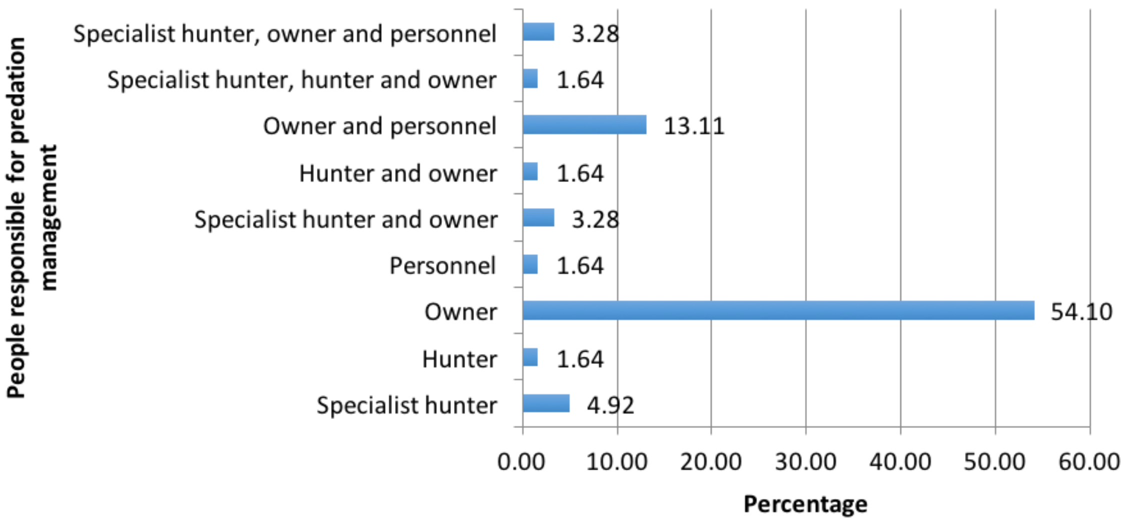

Figure A6: **Percentage of people responsible for managing predation on the wildlife ranches of WRSA members**

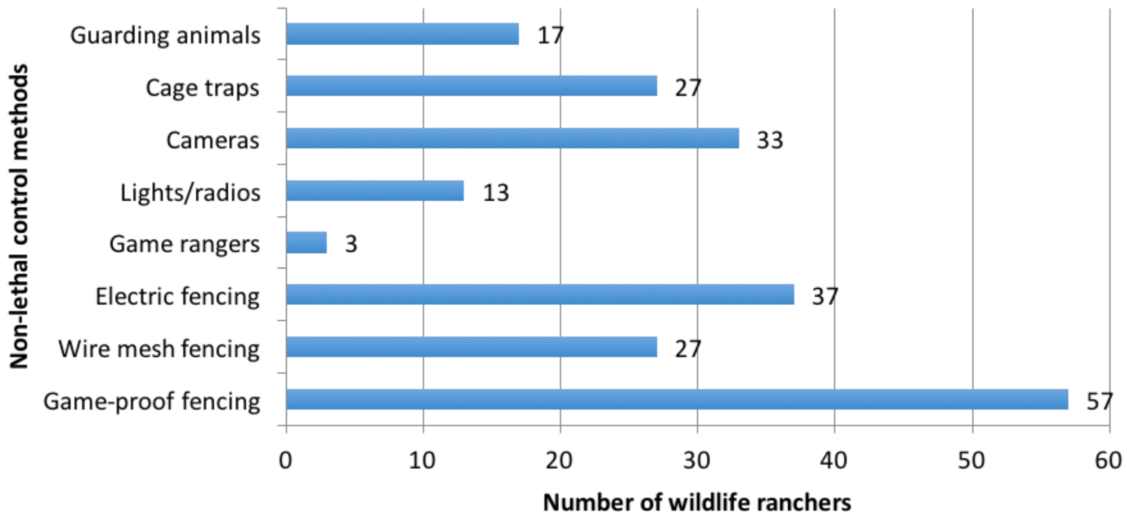

Figure A7: Non-lethal and assisting used by WRSA members in the Northwest province

Table A5: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on large antelope species

	Large antelope					
	Tobit		Probit		Truncated	
	Coefficient	P value	Coefficient	P value	Coefficient	P value
Wildlife rancher and rancher's perception						
Age 36 - 45	0.058	0.186	0.550	0.505	0.079	0.387
Age 56 - 65	0.063	0.221	-0.453	0.556	0.118	0.176
Wildlife ranch size	-0.958	0.191	0.000	**0.099***	-0.313	0.111
Topography: Plains	0.018	0.663	1.926	0.056	-0.087	0.265
Topography: Savannah	-0.005	0.900	3.019	**0.031***	-0.060	0.388
Black-back jackal as a priority predator	0.147	**0.001***	4.166	**0.003***	-0.045	0.613
Managerial factors						
Other farming enterprise: Cattle	-0.042	0.326	-0.903	0.293	0.021	0.765
Carcass as indication of predation	0.146	0.153	1.790	0.155	0.201	0.415
Number hunted as indication of predation	0.006	0.894	2.586	**0.017***	-0.122	**0.076***
Control methods						
Non-lethal control methods						
Guarding animals	0.024	0.535	2.283	**0.034***	-0.069	0.241
Cameras	-0.030	0.467	-0.807	0.387	-0.108	0.214
Lethal control methods						
Shooting	-0.038	0.521	-1.916	**0.074***	0.061	0.626
Owner manages predation	-0.076	0.195	-0.327	0.767	-0.021	0.842
Black-backed jackal hunted by owner	0.119	0.019*	2.513	**0.026***	0.049	0.600
Cragg's test statistic	43.863					
Significance	0.000					

Table A6: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on small antelope species

	Small antelope					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Age 46 - 55	-0.003	0.938	0.086	0.835	-0.038	0.620
Topography: Bush veld	-0.049	0.179	0.114	0.767	-0.141	**0.080***
Managerial factors						
Other farming enterprise: Cattle	-0.057	0.110	-0.131	0.735	-0.118	0.132
Number hunted as indication of predation	0.046	0.212	0.752	**0.072***	0.009	0.896
Owner manages predation	0.047	0.286	0.708	0.106	-0.029	0.742
Control methods						
Non-lethal control methods						
Caracal caught in cage traps	0.061	0.091	-0.917	0.815	0.139	**0.076***
Lethal control methods						
Cragg's test statistic	14.358					
Significance	0.045					

Table A7: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on scarce species/colour variant antelope

	Scarce species/colour variant antelope					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Age 46 – 55	-0.251	**0.088***	0.665	0.223	1.007	**0.000***
Age 56 – 65	-0.170	0.917	-0.462	0.446	1.193	**0.000***
Topography: Plains	0.139	0.274	0.248	0.629	-1.012	**0.000***
Topography: Bush veld	0.044	0.694	0.151	0.734	-0.833	**0.000***
Managerial factors						
Carcass as indication of predation	0.053	0.858	0.367	0.730	-8.706	**0.000***
Game counts as indication of predation	0.125	0.440	0.579	0.336	2.909	**0.000***
Number hunted as indication of predation	-0.238	**0.094***	-1.009	**0.071***	1.034	**0.000***
Control methods						
Non-lethal control methods						
Cage traps	0.143	0.363	1.332	**0.034***	-1.054	**0.000***
Guarding animals	0.135	0.283	-0.007	0.989	-0.103	**0.000***
Caracal caught in cage traps	-0.171	0.237	-0.764	0.182	0.153	**0.000***
Lethal control methods						
Shooting	0.261	0.200	0.802	0.259	3.989	**0.000***
Owner manages predation	0.114	0.574	0.110	0.880	3.782	**0.000***
Black-backed jackal hunted by owner	-0.086	0.576	-0.360	0.545	-2.025	**0.000***
Cragg's test statistic	88.698					
Significance	0.000					

Appendix B: Free State

Table B1: Number of wildlife ranchers surveyed and the hectares utilised in the Free State province

	Surveyed	Free State province	Percentage
Wildlife ranchers	64	157	40.76
Wildlife ranches (ha)	109 345	7 538 677	1.45

Table B2: Options used by wildlife ranchers to establish the numbers of wildlife in the Free State province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Amount of wildlife available to hunt
Number of wildlife ranchers	1	0	63	0
Percentage of province	1.56	0	98.44	0

Table B3: Three defined groups of antelope

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Nyala	*Tragelaphus angasii*	Impala	*Aepyceros melampus*	Sable	*Hippotragus niger*
Blue wildebeest	*Connochaetes taurinus*	Rhebok	*Redunca fulvorufula*	Black impala	*Aepyceros melampus*
Red hartebeest	*Alcelaphus buselaphus*	Springbok	*Antidorcas marsupialis*	Roan	*Hippotragus equinus*
Gemsbok	*Oryx gazelle*	Blesbok	*Damaliscus pygargus*	Copper springbok	*Antidorcas marsupialis*
Black wildebeest	*Connochaetes gnou*	Fallow deer	*Dama dama*	Lechwe	*Kobus lechwe*

Table B4: A summary of average hectare and average losses of antelope calculated for the Free State province

	Sample Size Column 1	Wildlife ranchers owning species Column 2	% Wildlife ranchers owning species Column 3	Number of individual animals lost due to predation Column 4	Average ha Column 5	Average number lost of each specie/ wildlife rancher Column 6	Average number lost/ha Column 7
				Large species			
Nyala	64	27	42.19	179	1 824.44	6.63	0.0036
Blue wildebeest	64	5	7.81	12	2 814.00	2.40	0.0009
Red hartebeest	64	7	10.94	14	2 828.57	2.00	0.0007
Gemsbok	64	11	17.19	63	1 867.27	5.73	0.0031
Black wildebeest	64	5	7.81	9	2 718.00	1.80	0.0007
				Small species			
Impala	64	33	51.56	596	1 779.09	18.06	0.0102
Rhebok	64	6	9.38	42	2 033.33	7.00	0.0034
Springbok	64	50	78.13	952	1 718.90	19.04	0.0111
Blesbok	64	34	53.13	386	1 953.97	11.35	0.0058
Fallow deer	64	4	6.25	57	1 067.50	14.25	0.0133
				Scarce species/colour variants			
Sables	64	22	34.38	46	1 454.55	2.09	0.0014
Black impala	64	9	14.06	61	1288.89	6.78	0.0053
Roan	64	11	17.19	18	2 114.55	1.64	0.0008
Copper springbok	64	6	9.38	54	720.83	9.00	0.0125
Lechwe	64	18	28.13	110	1 939.44	6.11	0.0032

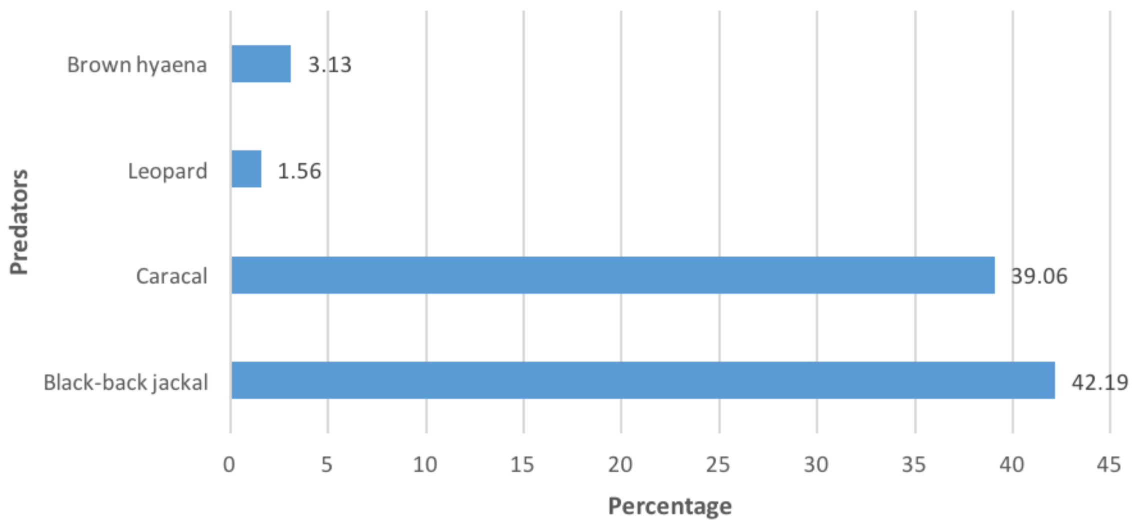

Figure B1: **Predators responsible for losses on large antelope species in the Free State province on wildlife ranches of WRSA members**

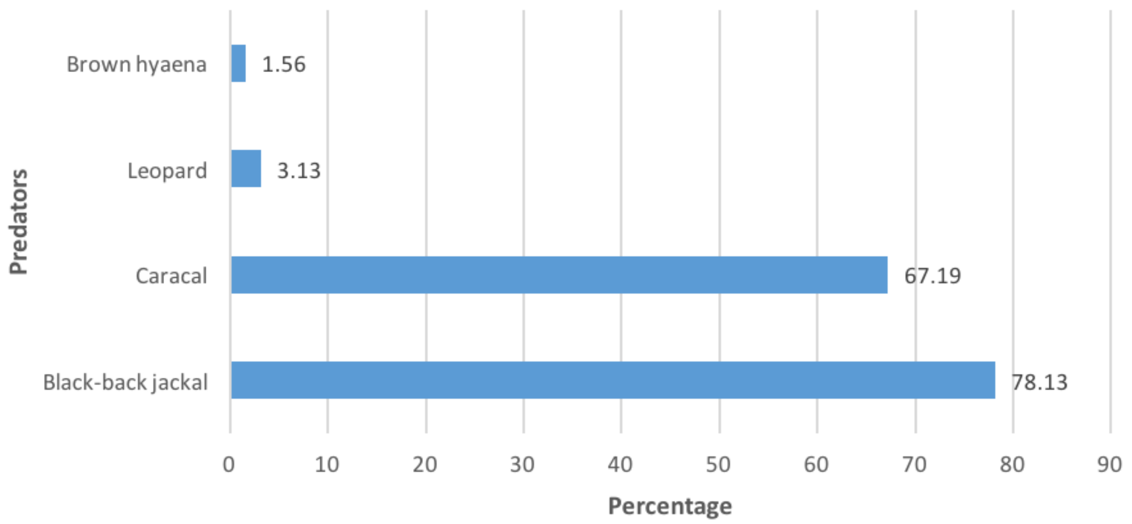

Figure B2: **Predators responsible for losses on small antelope species on wildlife ranches of WRSA members**

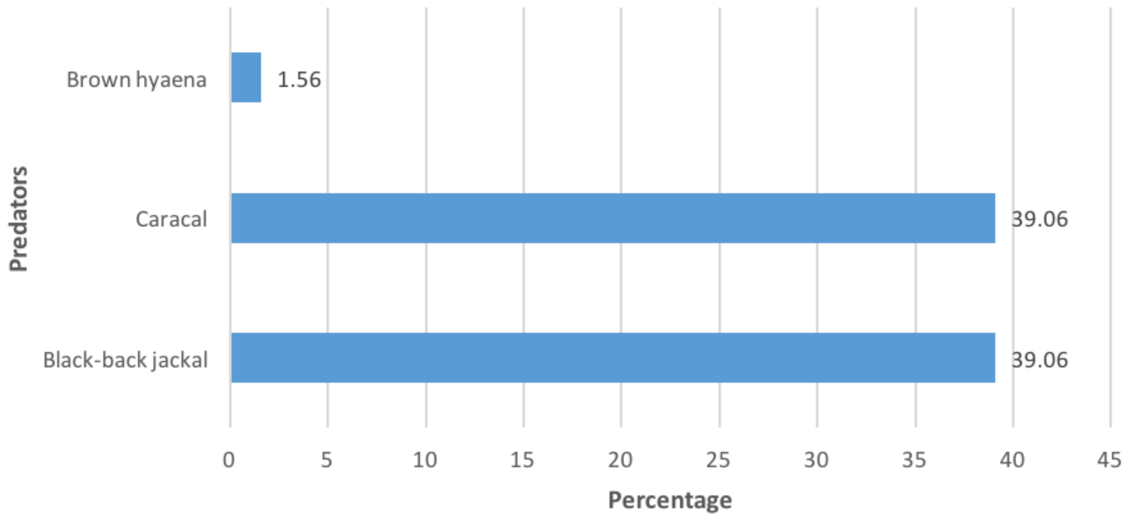

Figure B3: Predators responsible for losses on scarce species\colour variant antelope on wildlife ranches of WRSA members

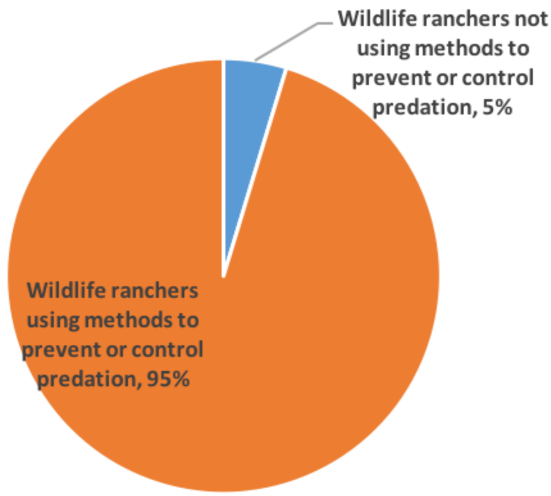

Figure B4: Percentage of WRSA members using predation management methods in the Free State province

Figure B5: Number of WRSA members using lethal control methods to control predators in the Free State province

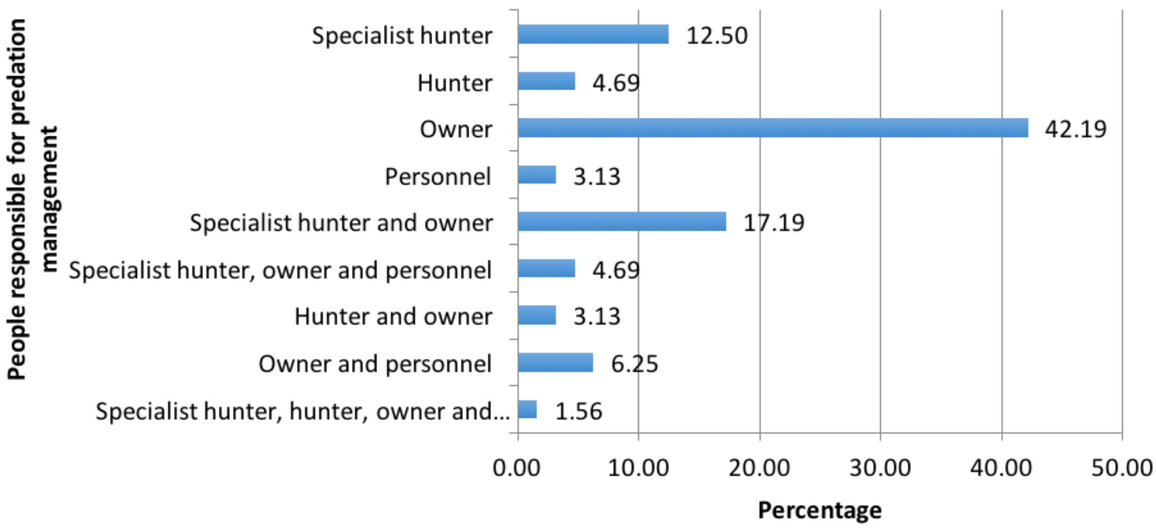

Figure B6: Percentage of people responsible for managing predation on the wildlife ranches of WRSA members

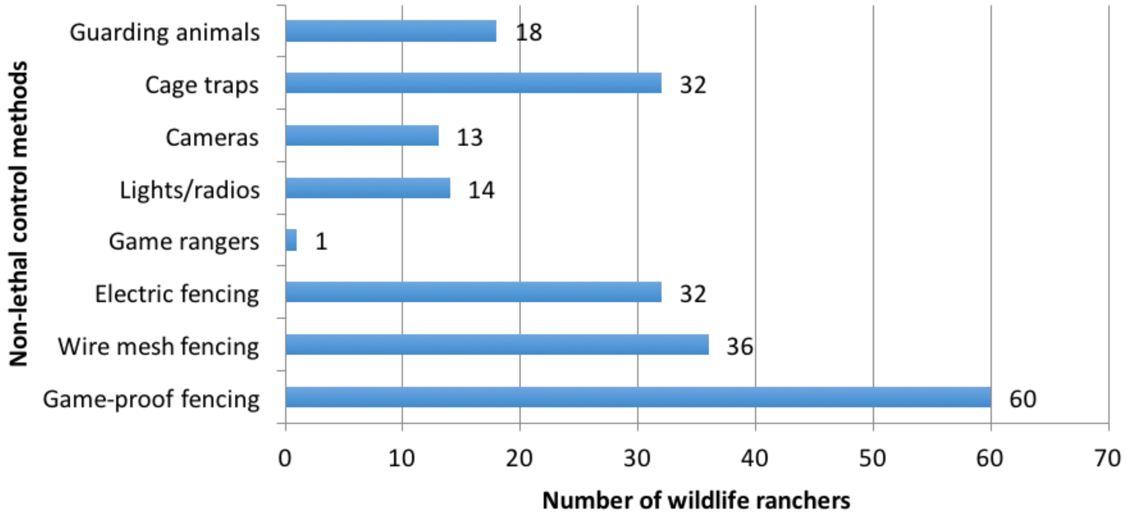

Figure B7: Non-lethal and assisting used by WRSA members in the Free State province

Table B5: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on large antelope species

	Large antelope					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Topography: Plains	0.113	0.278	0.119	0.899	0.112	0.689
Topography: Savannah	0.073	0.412	0.786	0.306	0.025	0.907
Caracal as a priority predator	0.589	**0.000***	4.062	**0.000***	-0.363	0.336
Managerial factors						
Other farming enterprise: Crops	0.027	0.759	-0.600	0.934	-0.034	0.892
Number hunted as indication of predation	0.096	0.340	0.881	0.224	0.601	0.201
Control methods						
Non-lethal control methods						
Caracal caught in cage traps	0.002	0.980	0.201	0.744	0.159	0.514
Lethal control methods						
Shooting	-0.246	**0.068***	-0.279	0.833	-0.859	**0.016***
Specialist hunter manages predation	-0.114	0.203	0.151	0.832	-0.924	**0.044***
Owner manages predation	0.038	0.704	0.217	0.792	-0.057	0.835
Caracal hunted by owner	0.091	0.347	1.084	0.205	-0.192	0.501
Cragg's test statistic	35.515					
Significance	0.000					

Table B6: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on small antelope species

	Small antelope					
	Tobit		Probit		Truncated	
	Coefficient	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Wildlife rancher and rancher's perception						
Topography: Plains	-0.270	**0.033***	-1.237	0.121	-0.194	0.573
Managerial factors						
Control methods						
Non-lethal control methods						
Lights and/radios	-0.014	0.921	0.181	0.776	-0.044	0.908
Caracal caught in cage traps	-0.132	0.245	0.164	0.726	0.171	0.605
Lethal control methods						
Shooting	0.382	**0.058***	1.587	**0.028***	0.177	0.794
Owner manages predation	-0.058	0.643	-0.191	0.717	-0.047	0.896
Cragg's test statistic	4.841					
Significance	0.564					

Table B7: Results of the Tobit and Double hurdle model to identify variables that affect the occurrence and level of predation on scarce species/colour variant antelope

	Small antelope					
	Tobit		Probit		Truncated	
	Coefficient	P value	Coefficient	P value	Coefficient	P value
Wildlife rancher and rancher's perception						
Topography: Mountainous	0.111	0.290	1.910	0.244	0.230	0.438
Topography: Savannah	0.046	0.607	2.381	**0.097***	-0.250	0.279
Black-back jackal as a priority predator	0.364	**0.001***	3.357	**0.012***	0.130	0.633
Caracal as a priority predator	0.280	**0.020***	4.183	**0.015***	-0.119	0.680
Managerial factors						
Other farming enterprise: Crops	0.094	0.328	1.197	0.204	0.075	0.767
Non-lethal control methods						
Guarding animals	-0.234	**0.019***	-1.907	**0.088***	-0.478	0.168
Lethal control methods						
Shooting	0.087	0.669	-0.582	0.705	0.477	0.524
Owner manages predation	0.173	0.138	-0.160	0.898	0.333	0.354
Black-backed jackal hunted by owner	-0.096	0.392	-0.258	0.820	-0.033	0.913
Caracal hunted by owner	0.096	0.317	-2.059	0.124	0.431	0.130
Cragg's test statistic	33.445					
Significance	0.000					

Appendix C: Eastern Cape Province

Table C1: Number of wildlife ranchers surveyed and the hectares utilised in the Eastern Cape province

	Surveyed	Eastern Cape province	Percentage
Wildlife ranchers	11	137	8.03
Wildlife ranches (ha)	38 350	13 644 822	0.28

Table C2: Options used by wildlife ranchers to establish the numbers of wildlife in the Eastern Cape province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	0	0	11	0
Percentage of province	0	0	100	0

Table C3: Three defined groups of antelope species

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Nyala	*Tragelaohus angasii*	Impala	*Aepyceros melampus*	Black impala	*Aepyceros melampus*
Blue wildebeest	*Connochaetes taurinus*	Blesbok	*Damaliscus pygargus*	Bontebok	*Damaliscus pygargus dorcas*
		Klipspringer	*Oreotragus oreotragus*		
		Rhebok	*Redunca fulvorufula*	Copper springbok	*Antidorcas marsupialis*
		Springbok	*Antidorcas marsupialis*		

Table C4: A summary of average hectares and average losses of antelope calculated for the Eastern Cape province

	Sample size Column 1	Wildlife ranchers owning species Column 2	% Wildlife ranchers owning species Column 3	Number of individual animals lost due to predation Column 4	Average ha Column 5	Average number of each species lost/ wildlife rancher Column 6	Average number lost/ha Column 7
Large species							
Nyala	11	6	54.55	75	3608.33	12.5	0.0035
Blue wildebeest	11	1	9.09	2	2 500.00	2	0.0008
Small species							
Impala	11	8	72.73	155	4 487.50	19.38	0.0043
Blesbok	11	4	36.36	59	5 425.00	14.75	0.0027
Klipspringer	11	2	18.18	21	1 850.00	10.50	0.0057
Rhebok	11	2	18.18	25	1 750.00	12.50	0.0071
Springbok	11	7	63.64	705	4 814.29	100.71	0.0209
Scarce species/colour variants							
Black impala	11	1	9.09	6	650.00	6	0.0092
Bontebok	11	3	27.27	42	2100	14	0.0067
Copper springbok	11	1	9.09	7	650.00	7	0.0108

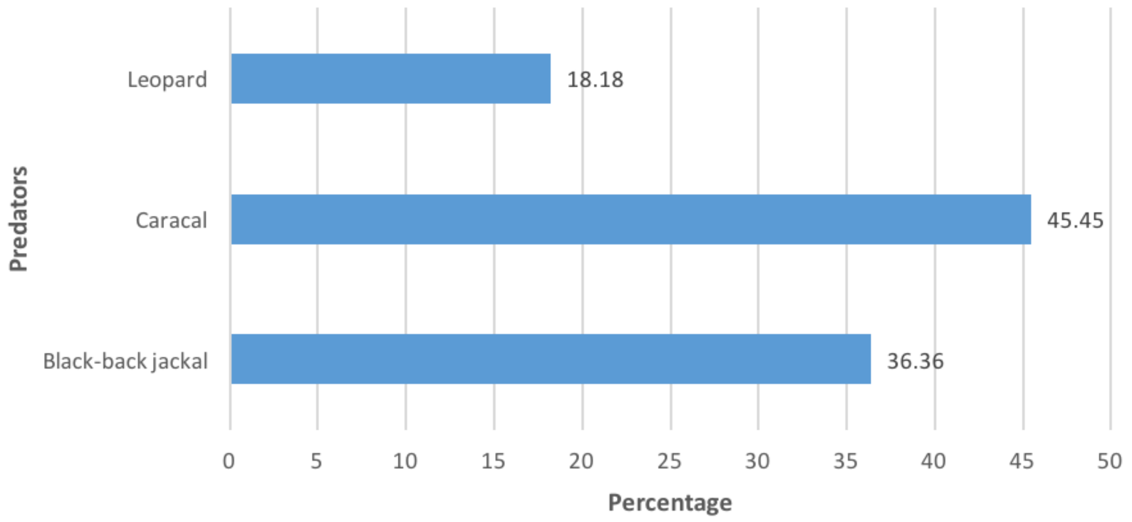

Figure C1: **Predators responsible for losses on large antelope species on the wildlife ranches of WRSA members**

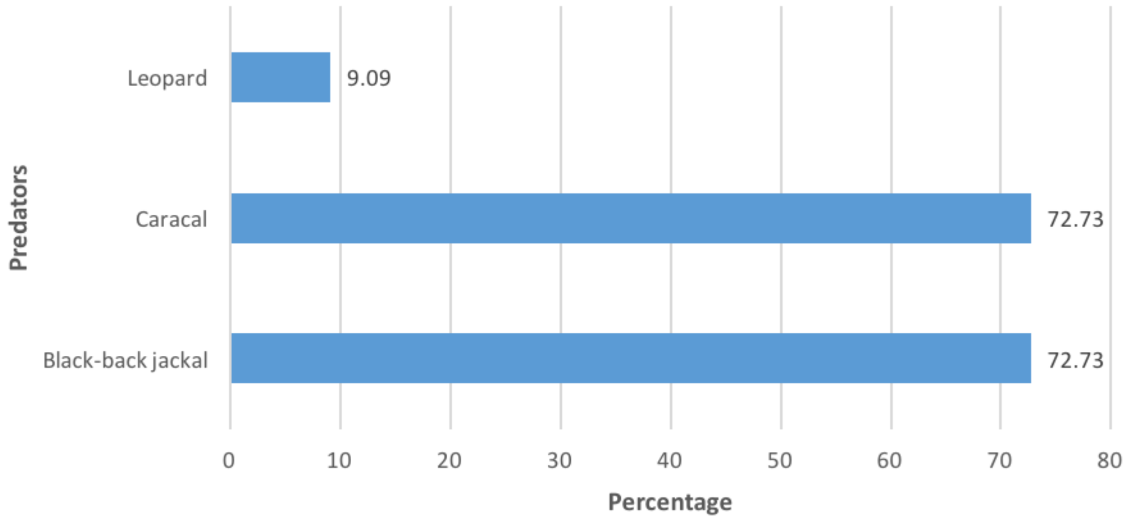

Figure C2: **Predators responsible for losses on small antelope species on the wildlife ranches of WRSA members**

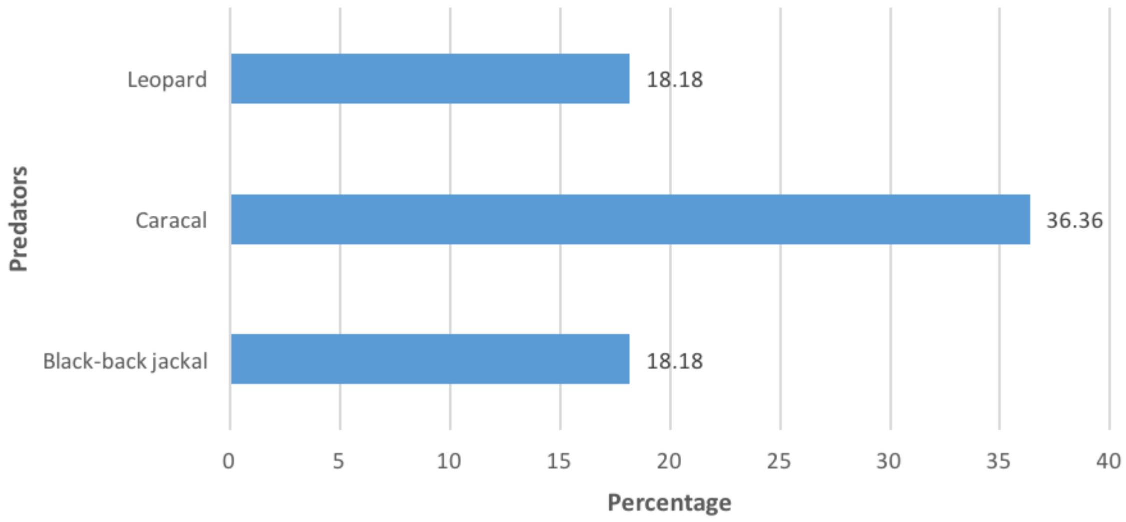

Figure C3: **Predators responsible for losses on scarce species/colour variant antelope on the wildlife ranches of WRSA members**

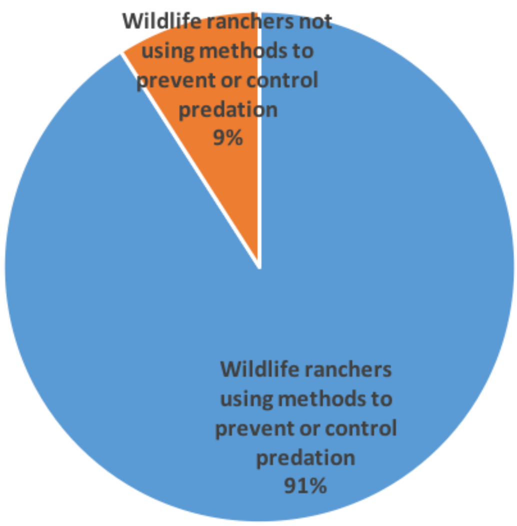

Figure C4: **Percentage of WRSA members using predation management methods in the Eastern Cape province**

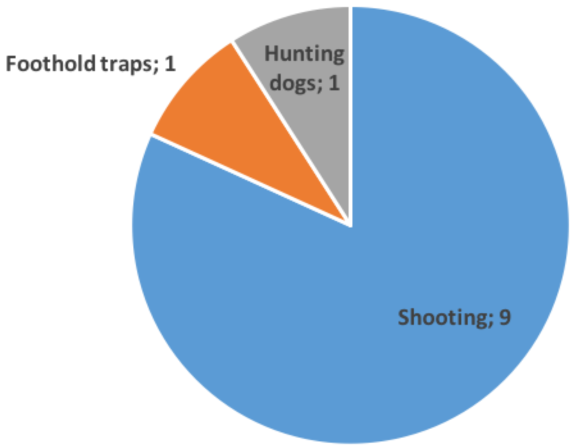

Figure C5: Number of WRSA members using lethal control methods to control predators in the Eastern Cape province

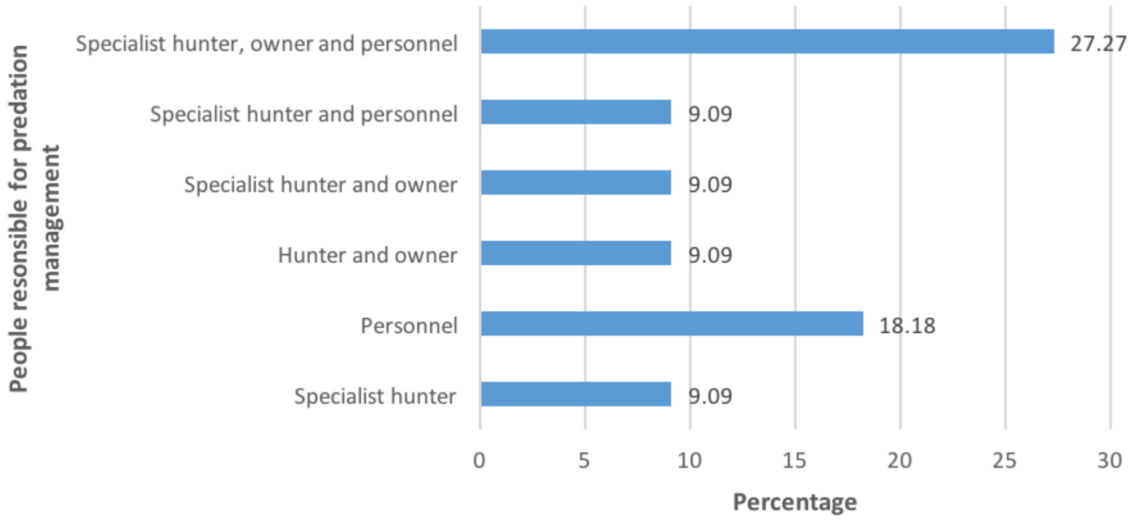

Figure C6: Percentage of people responsible for managing predation on the wildlife ranches of WRSA members

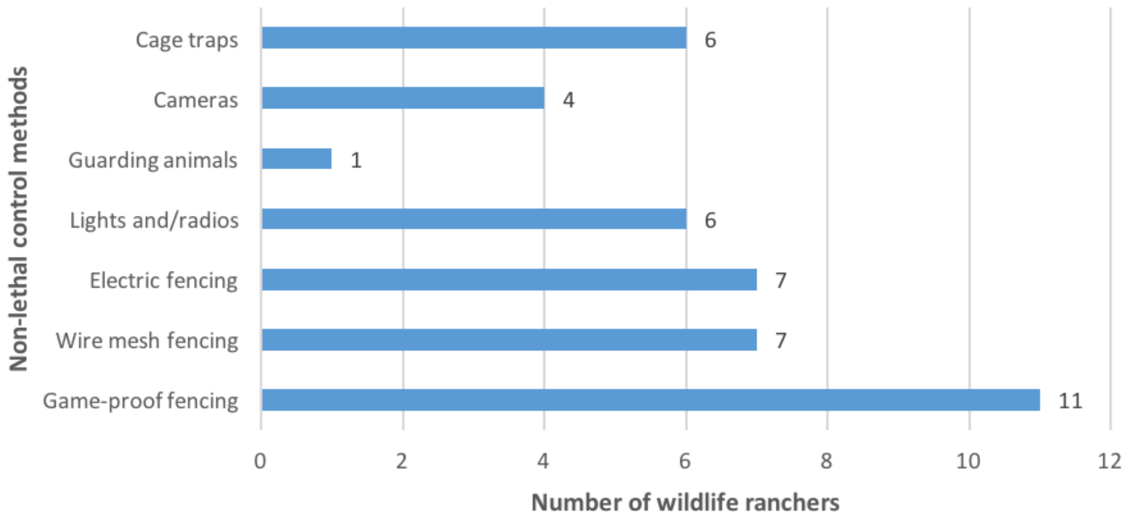

Figure C7: **Non-lethal and assisting used by WRSA members in the Eastern Cape province**

Appendix D: Kwa-Zulu Natal Province

Table D1: Number of wildlife ranchers surveyed and the hectares utilised in the Kwa-Zulu Natal province

	Surveyed	Kwa-Zulu Natal province	Percentage
Wildlife ranchers	3	69	4.35
Wildlife ranches (ha)	3 691	5 329 640	0.07

Table D2: Options used by wildlife ranchers to establish the numbers of wildlife in the Kwa-Zulu Natal province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	0	0	3	0
Percentage of province	0	0	100	0

Table D3: Three defined groups of antelope species

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Nyala	*Tragelaohus angasii*	Impala	*Aepyceros melampus*	Black impala	*Aepyceros melampus*
Blue wildebeest	*Connochaetes taurinus*	Bushbuck	*Tragelaphus scriptus*		
		Reedbuck	*Redunca arundinum*		

Table D4: A summary of average hectares and average losses of antelope calculated for the Kwa-Zulu Natal province

	Sample size Column 1	Wildlife ranchers owning species Column 2	% Wildlife ranchers owning species Column 3	Number of individual animals lost due to predation Column 4	Average ha Column 5	Average number of each species lost/wildlife rancher Column 6	Average number lost/ha Column 7
Large species							
Nyala	3	2	66.67	2	495.5	1	0.0020
Blue wildebeest	3	1	33.33	1	900.00	1	0.0011
Small species							
Impala	3	2	66.67	510	2 250.00	255	0.1133
Bushbuck	3	1	33.33	25	2 700.00	25	0.0093
Reedbuck	3	3	100.00	24	1 230.33	8	0.0065
Scarce species/colour variants							
Black impala	2	1	50.00	2	91	2	0.0220

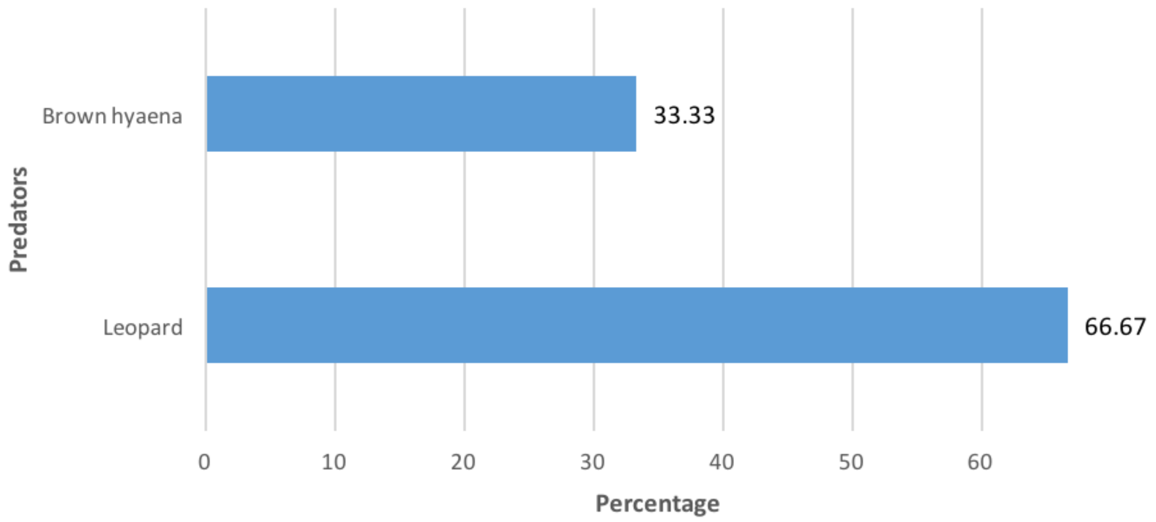

Figure D1: **Predators responsible for losses on large antelope species on the wildlife ranches of WRSA members**

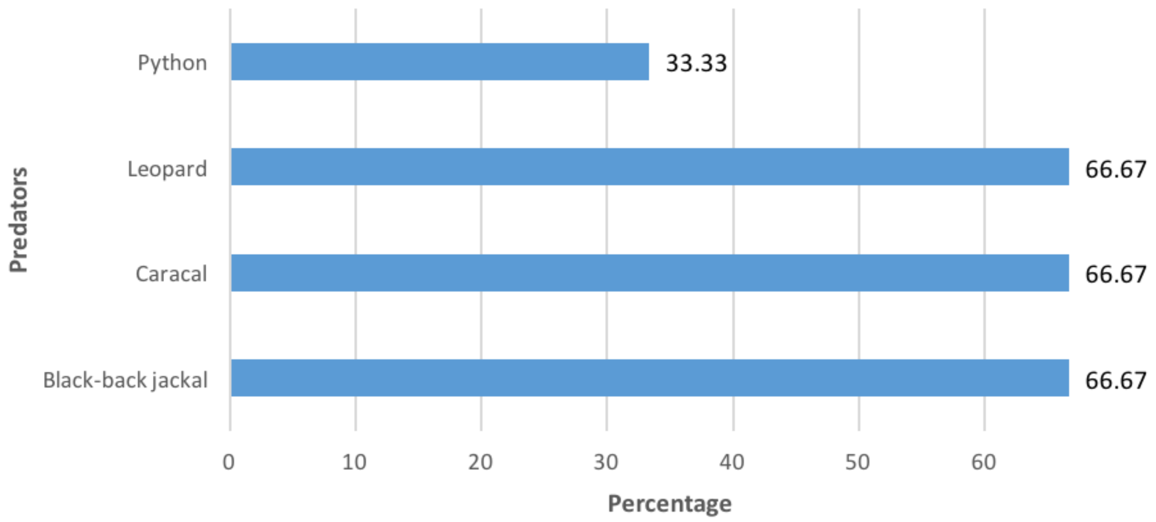

Figure D2: **Predators responsible for losses on scarce species/colour variant antelope on the wildlife ranches of WRSA members**

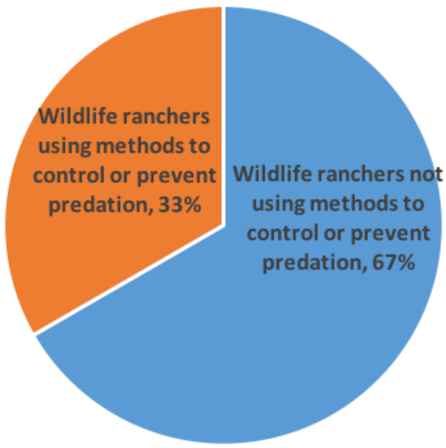

Figure D3: **Percentage of WRSA members using predation management methods in the Kwa-Zulu Natal province**

Figure D4: **Number of WRSA members using lethal control methods to control predators in the Kwa-Zulu Natal province**

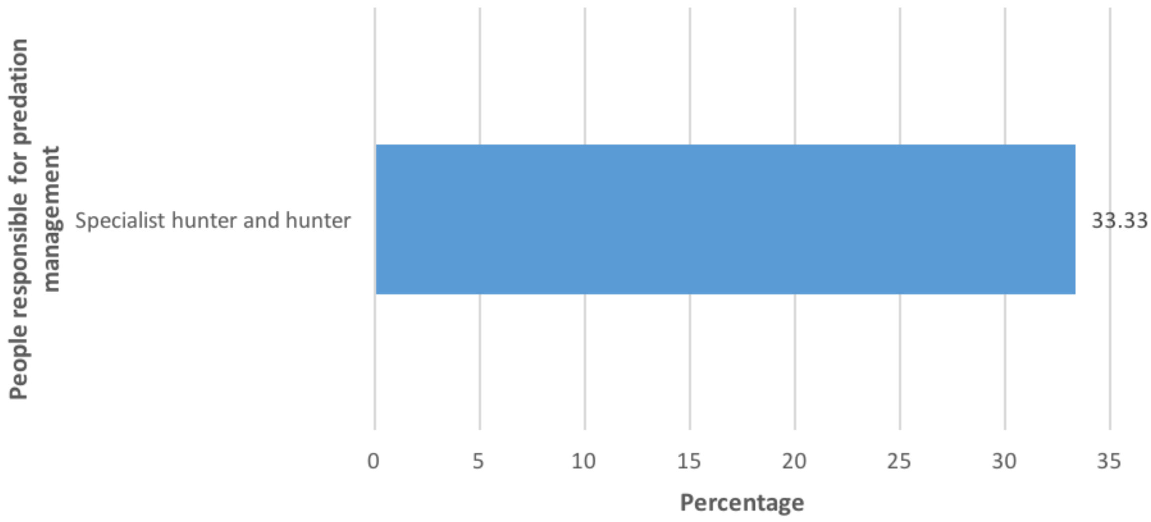

Figure D5: **Percentage of people responsible for managing predation on the wildlife ranches of WRSA members**

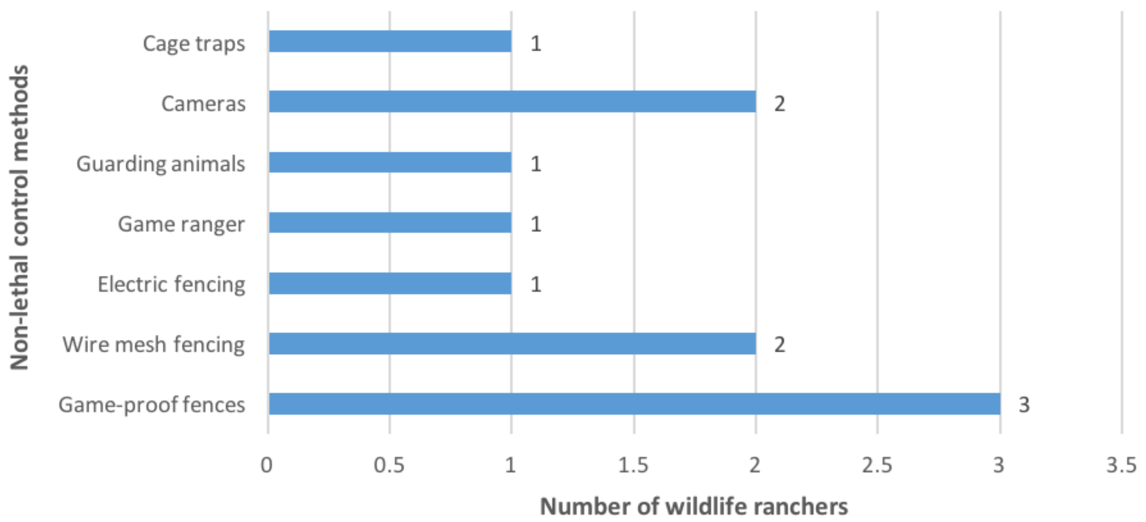

Figure D6: **Non-lethal and assisting used by WRSA members in the Kwa-Zulu Natal province**

Appendix E: Mpumalanga Province

Table E1: Number of wildlife ranchers surveyed and the hectares utilised in the Mpumalanga province

	Surveyed	Mpumalanga	Percentage
Wildlife ranchers	4	76	5.26
Wildlife ranches (ha)	4 700	3 243 931	0.14

Table E2: Options used by wildlife ranchers to establish the numbers of wildlife in the Mpumalanga province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	0	0	4	0
Percentage of province	0	0	100	0

Table E3: Two defined groups of antelope species

Large species		Small species	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**
Black wildebeest	*Connochaetes gnou*	Impala	*Aepyceros melampus*
Nyala	*Tragelaphus angasii*	Springbok	*Antidorcas marsupialis*
Blue wildebeest	*Connochaetes taurinus*	Blesbok	*Damaliscus pygargus phillipsi*
Eland	*Tragelaphus oryx*	Steenbok	*Raphicerus campestris*
Red hartebeest	*Alcelaphus buselaphus*	Duiker	*Sylvicapra grimmia*
		Oribi	*Ourebi aourebi*

Table E4: A summary of average hectares and average losses of antelope calculated for the Mpumalanga province

	Sample size	Wildlife ranchers owning species	% Wildlife ranchers owning species	Number of individual animals lost due to predation	Average ha	Average number of each species lost/wildlife rancher	Average number lost/ha
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Large species							
Nyala	4	1	25	5	2 000.00	5.00	0.0025
Blue wildebeest	4	1	25	15	2 000.00	15.00	0.0075
Eland	4	1	25	10	2 000.00	10.00	0.0050
Red hartebeest	4	1	25	6	900.00	6.00	0.0067
Black wildebeest	4	1	25	6	1 600.00	6.00	0.0038
Small species							
Impala	4	3	75	85	1 033.33	28.33	0.0274
Springbok	4	1	25	60	1 600.00	60.00	0.0375
Blesbok	4	3	75	84	1 500.00	28.00	0.0187
Steenbok	4	1	25	5	200.00	5.00	0.0250
Duiker	4	1	25	5	200.00	5.00	0.0250
Oribi	4	2	50	11	900.00	5.50	0.0061

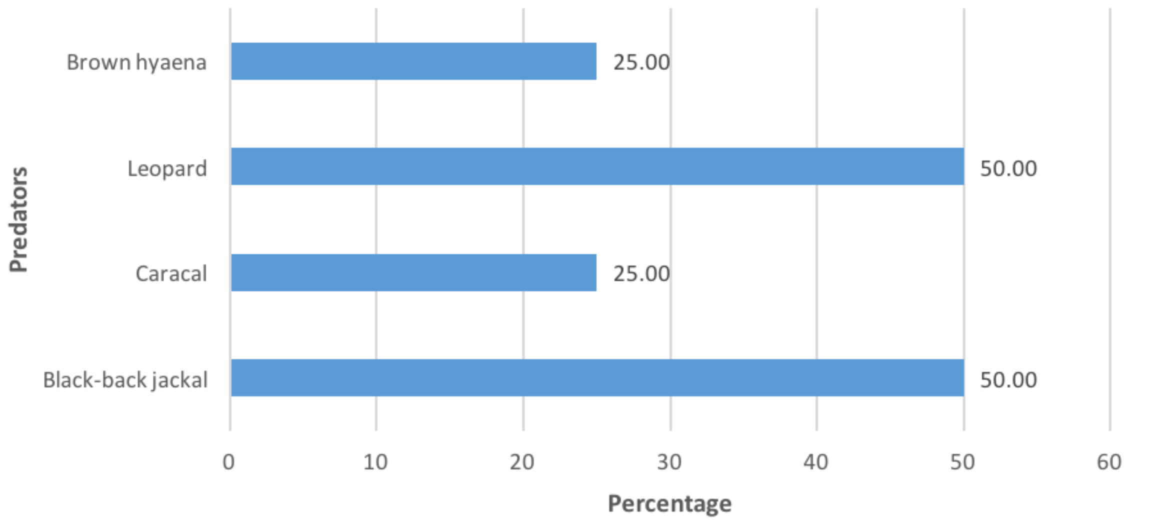

Figure E1: **Predators responsible for losses on large antelope species on the wildlife ranches of WRSA members**

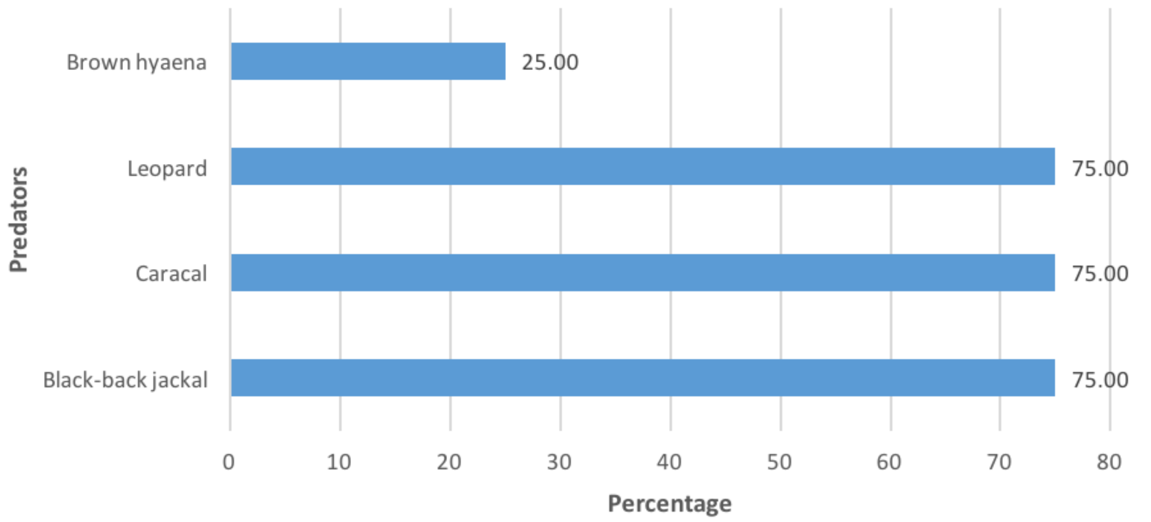

Figure E2: **Predators responsible for losses on small antelope species on the wildlife ranches of WRSA members**

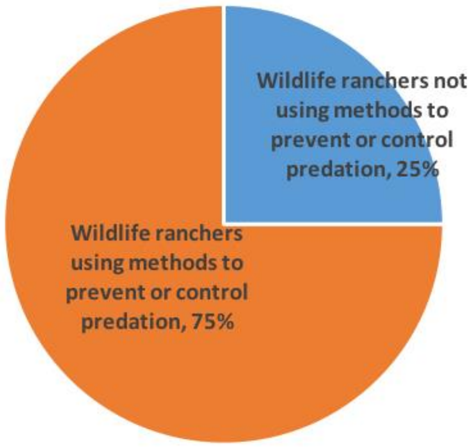

Figure E3: **Percentage of WRSA members using predation management methods in the Mpumalanga province**

Figure E4: **Number of WRSA members using lethal control methods to control predators in the Mpumalanga province**

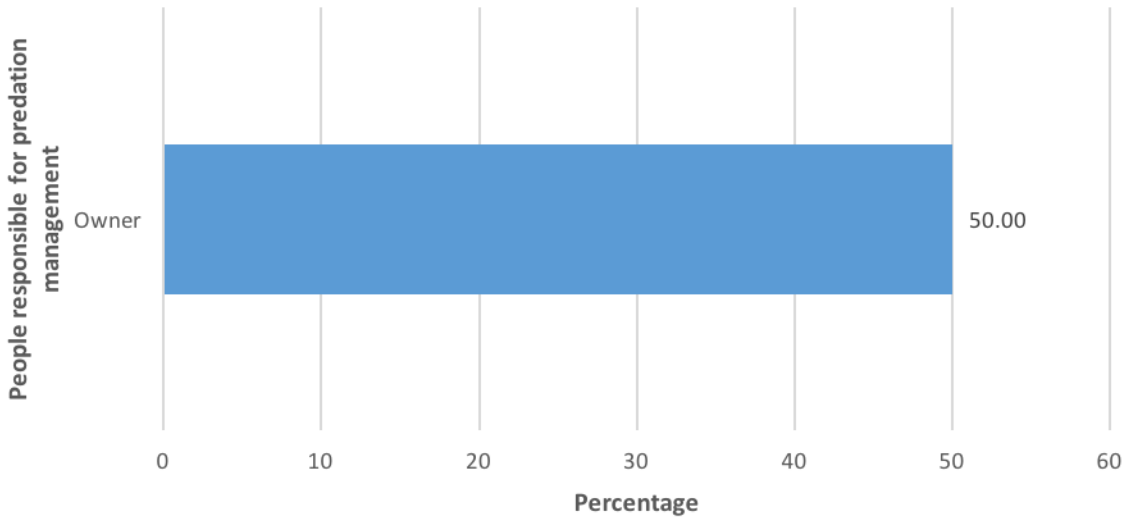

Figure E5: Percentage of people responsible for managing predation on the wildlife ranches of WRSA members

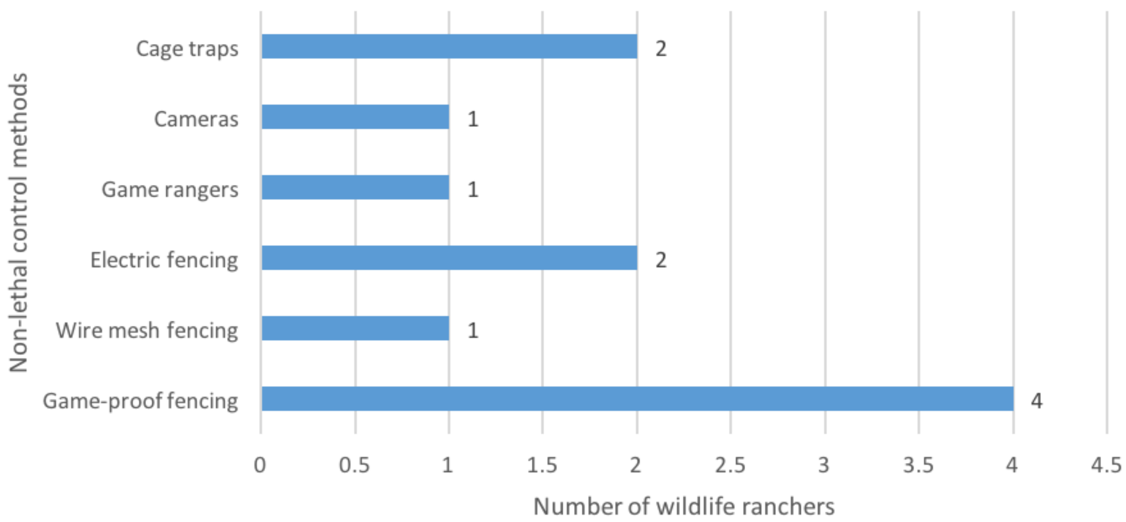

Figure E6: Non-lethal and assisting used by WRSA members in the Mpumalanga province

Appendix F: Northern Cape Province

Table F1: Number of wildlife ranchers surveyed and the hectares utilised in the Northern Cape province

	Surveyed	Northern Cape province	Percentage
Wildlife ranchers	8	119	6.72
Wildlife ranches (ha)	112 600	29 089 367	0.39

Table F2: Options used by wildlife ranchers to establish the numbers of wildlife in the Northern Cape

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	0	0	8	0
Percentage of province	0	0	100	0

Table F3: Three defined groups of antelope species

Large species		Small species		Scarce species/colour variants	
Wildlife specie	**Scientific name**	**Wildlife specie**	**Scientific name**	**Wildlife specie**	**Scientific name**
Nyala	*Tragelaphus angasii*	Impala	*Aepyceros melampus*	Bontebok	*Damaliscus pygargus dorcas*
Kudu	*Tragelaphus strepsiceros*	Blesbok	*Damaliscus pygargus*		
Gemsbok	*Oryx gazelle*	Lechwe	*Kobus leche*		
		Rhebok	*Pelea capreolus*		
		Springbok	*Antidorcas marsupialis*		

Table F4: A summary of average hectares and average losses of antelope calculated for the Northern Cape province

	Sample size	Wildlife ranchers owning species	% Wildlife ranchers owning species	Number of individual animals lost due to predation	Average ha	Average number of each species lost/wildlife rancher	Average number lost/ha
	Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**
				Large species			
Nyala	8	4	50	29	18 750.00	7.25	0.0004
Kudu	8	3	37.5	15	22 100.00	5.00	0.0002
Gemsbok	8	3	37.5	5	11 166.67	1.67	0.0001
				Small species			
Impala	8	4	50	172	17 950.00	43.00	0.0024
Rhebok	8	3	37.5	60	28 166.67	20.00	0.0007
Spriingbok	8	7	87.5	495	15 371.43	70.71	0.0046
Lechwe	8	1	12.5	10	2 700.00	10.00	0.0037
Blesbok	8	1	12.5	2	15 000.00	2.00	0.0001
				Scarce species/colour variants			
Bontebok	8	1	12.5	3	11 000.00	3.00	0.0003

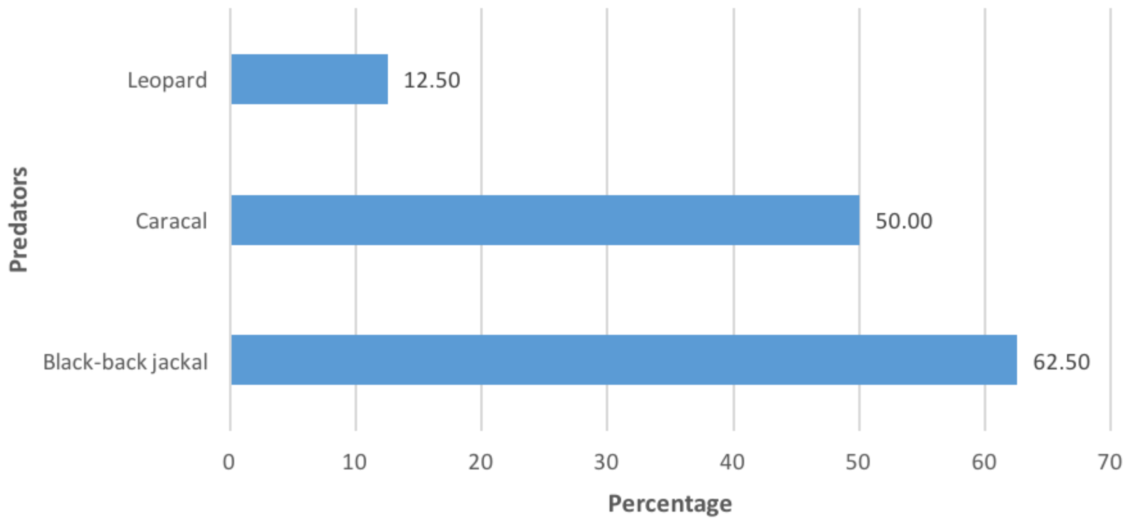

Figure F1: Predators responsible for losses on large antelope species on the wildlife ranches of WRSA members

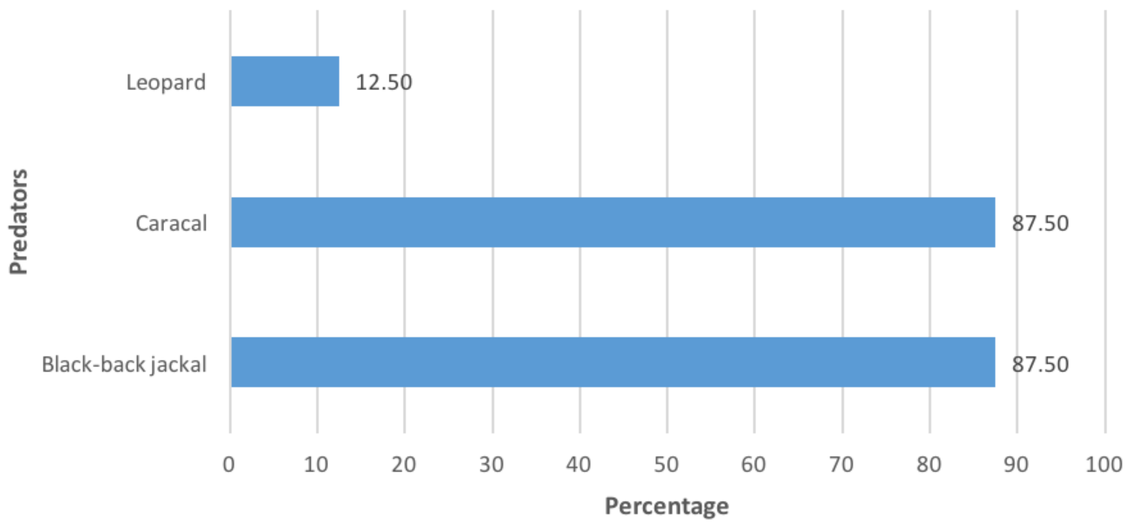

Figure F2: Predators responsible for losses on small antelope species on the wildlife ranches of WRSA members

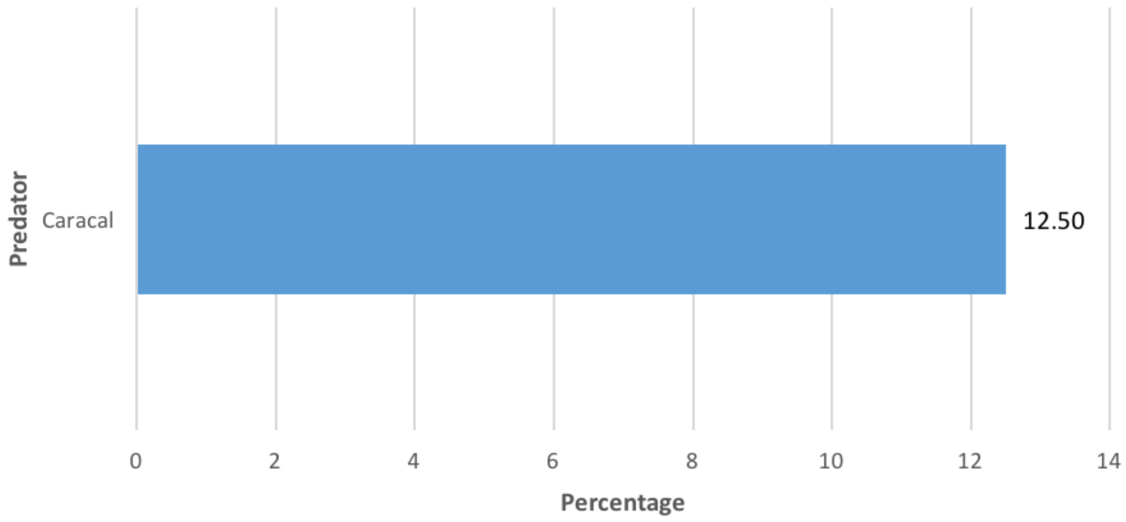

Figure F3: **Predators responsible for losses on scarce species/colour variant antelope on the wildlife ranches of WRSA members**

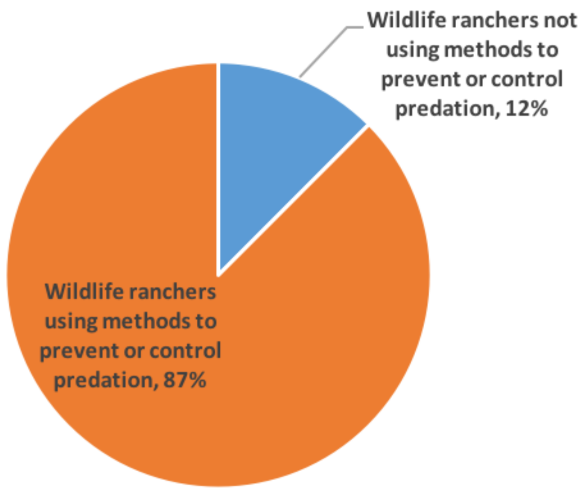

Figure F4: **Percentage of WRSA members using predation management methods in the Northern Cape province**

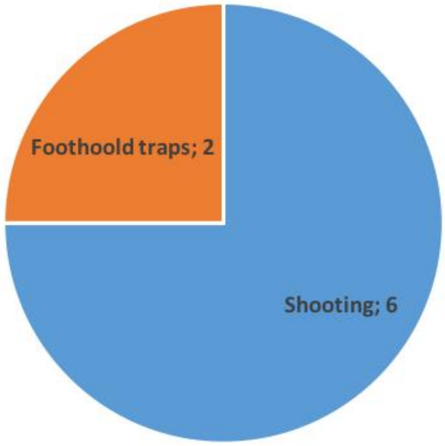

Figure F5: Number of WRSA members using lethal control methods to control predators in the Northern Cape province

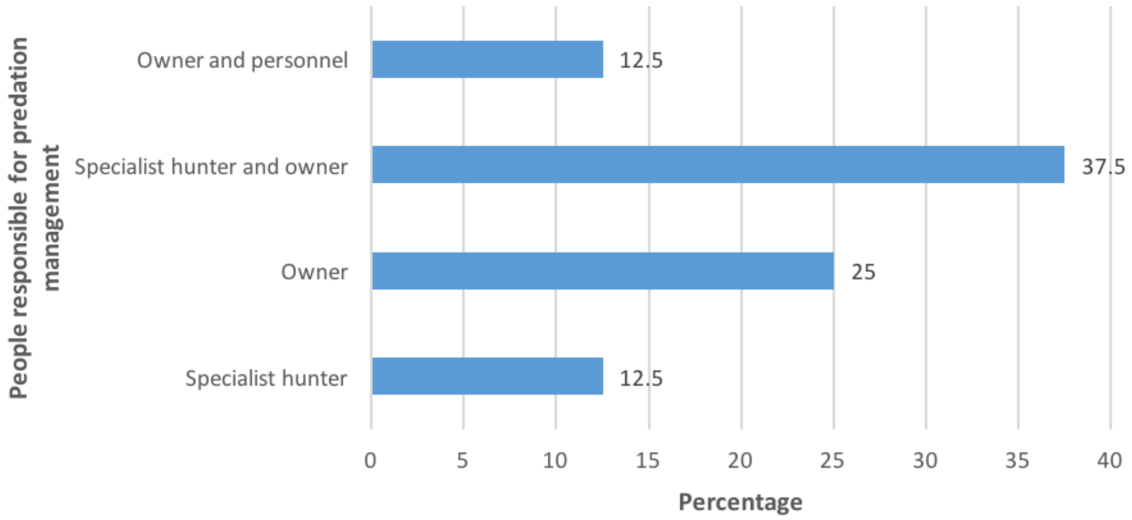

Figure F6: Percentage of people responsible for managing predation on the wildlife ranches of WRSA members

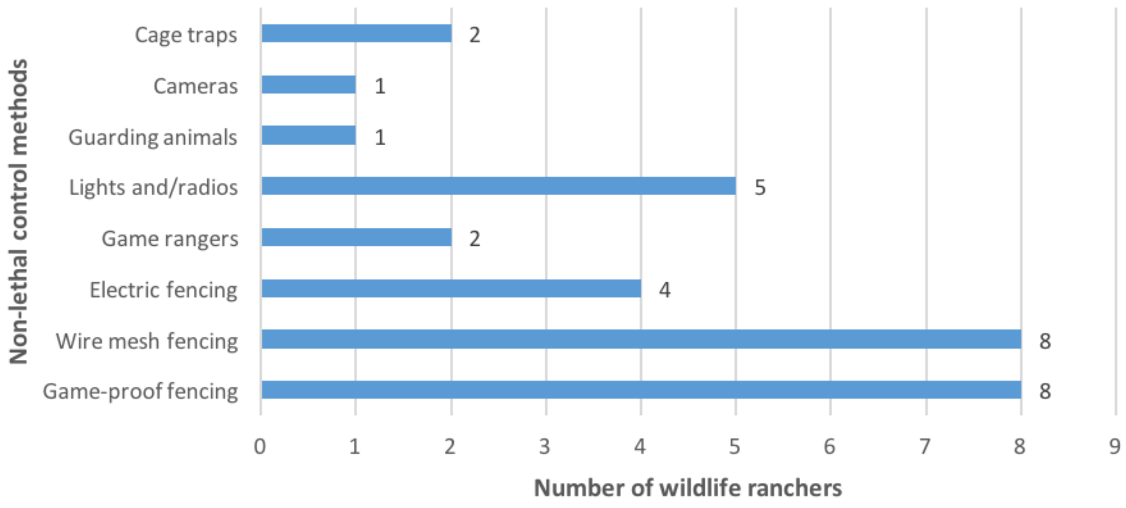

Figure F7: **Non-lethal and assisting used by WRSA members in the Northern Cape province**

Appendix G: Western Cape Province

Table G1: Number of wildlife ranchers surveyed and the hectares utilised in the Western Cape province

	Surveyed	Western Cape province	Percentage
Wildlife ranchers	2	59	3.39
Wildlife ranches (ha)	3 856	9 105 821	0.04

Table G2: Options used by wildlife ranchers to establish the numbers of wildlife in the Western Cape province

	Option 1 Physical counting	Option 2 Rand value	Option 3 Estimating	Option 4 Number of wildlife available to hunt
Number of wildlife ranchers	0	0	2	0
Percentage of province	0	0	100	0

Table G3: One defined group of antelope species

	Small species
Wildlife specie	**Scientific name**
Sprinbok	*Antidorcas marsupialis*

Table G4: A summary of average hectares and average losses of antelope calculated for the Western Cape province

	Sample size	Wildlife ranchers owning species	% Wildlife ranchers owning species	Number of individual animals lost due to predation	Average ha	Average number of each species lost/wildlife rancher	Average number lost/ha
	Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**
				Small species			
Springbok	2	1	50	20	3 000.00	20	0.0067

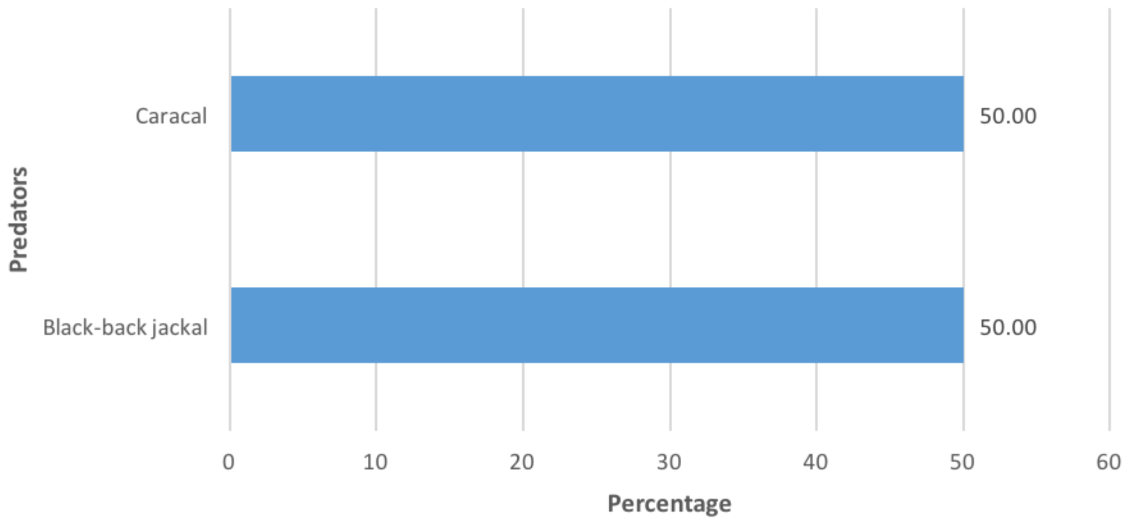

Figure G1: **Predators responsible for losses on small antelope species on the wildlife ranches of WRSA members**

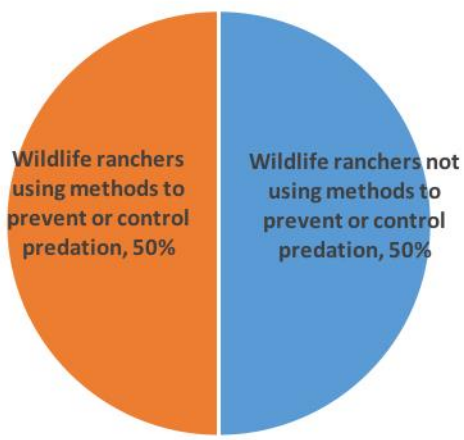

Figure G2: **Percentage of WRSA members using predation management methods in the Western Cape province**

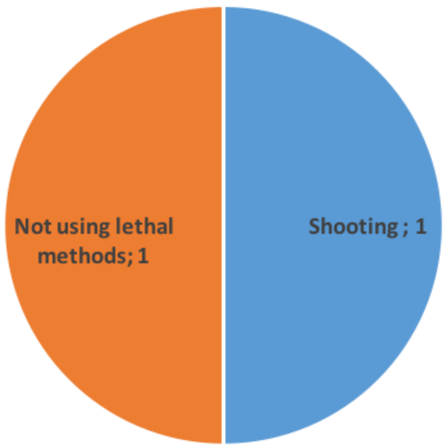

Figure G3: **Number of WRSA members using lethal control methods to control predators in the Western Cape province**

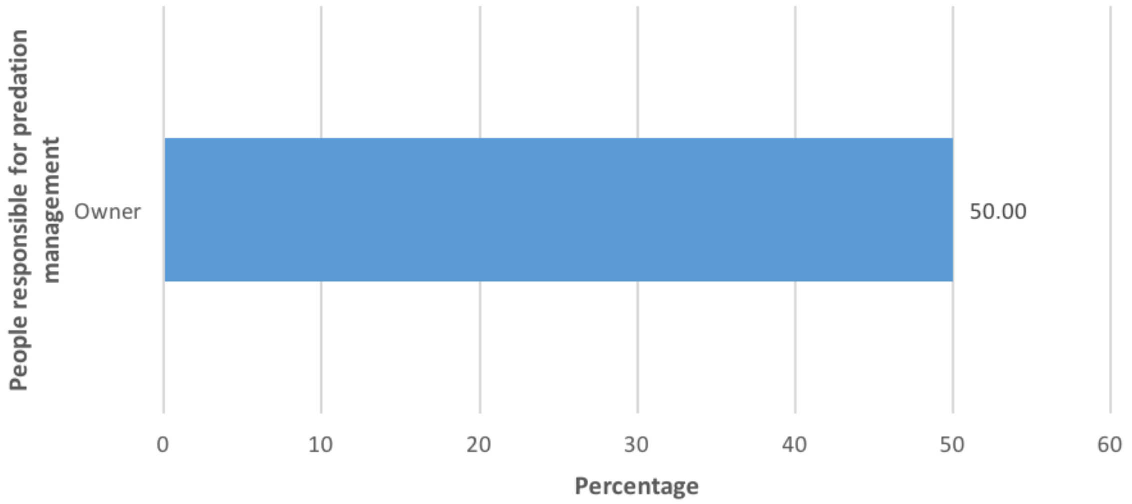

Figure G4: **Percentage of people responsible for managing predation on the wildlife ranches of WRSA members**

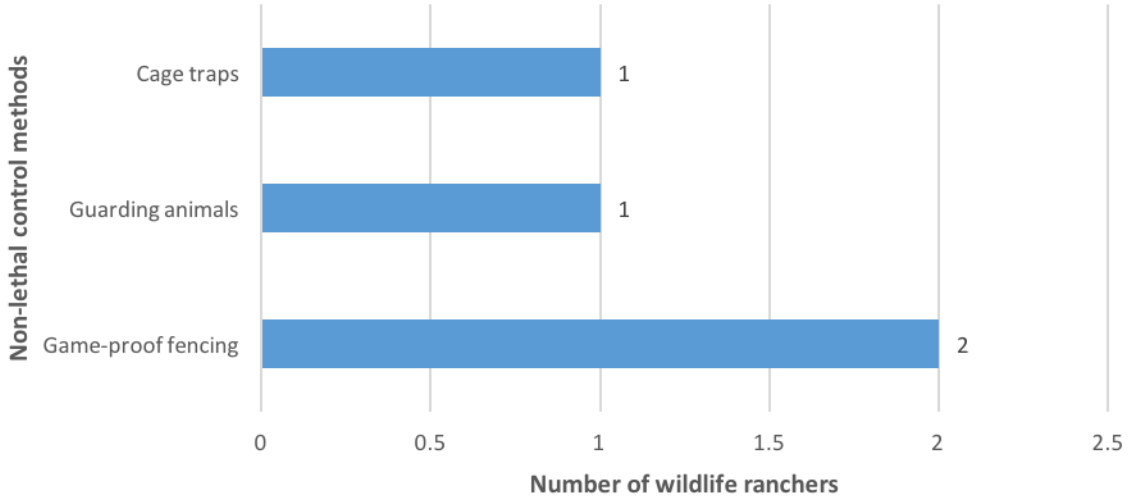

Figure G5: **Non-lethal and assisting used by WRSA members in the Western Cape province**

Appendix H: Common and scientific names and auction prices of wildlife species

Table H1: Common names, scientific names of wildlife species reported by the respondents, as well as the average auction prices for the species during 2014 & 2015

Species named by wildlife ranchers	Scientific name[1]	Common name[1]	Average ZAR 2014/15[2]
African buffalo	*Syncerus caffer* (Sparrman, 1779)	African buffalo	999 941
Black wildebeest	*Connochaetes gnou* (Zimmerman, 1780)	Black wildebeest	4 514
Blesbok	*Damaliscus pygargus phillipsi* (Pallas, 1767)	Blesbok	4 153
Blesbok (copper) Blesbok (masked face) Blesbok (white) Blesbok (yellow)			949 330
Blue wildebeest	*Connochaetes taurinus* (Burchell, 1823)	Blue wildebeest	14 495
Blue wildebeest (golden) Blue wildebeest (king) Blue wildebeest (split)			1 230 486
Bontebok	*Damaliscus pygargus dorcas* (Pallas, 1767)	Bontebok	121 817
Bushbuck	*Tragelaphus scriptus* (Pallas, 1766)	Bushbuck	21 282
Cape Grysbok	*Raphicerus melanotis* (Thunberg, 1811)	Cape Grysbok	24 417
Common duiker	*Sylvicapra grimmia* (Linnaeus, 1758)	Common duiker	13 788
Common ostrich	*Struthiocamelus* (Linnaeus, 1758)	Common ostrich	8 518
Common warthog	*Phacochoerusafricanus* (Gmelin, 1788)	Common warthog	400
Eland	*Tragelaphus oryx* (Pallas, 1766)	Eland	9 325
Eland (Livingston)			282 430
Fallow deer	*Damadama* (Linnaeus, 1758)	Fallow deer	5 227
Gemsbok	*Oryx gazella* (Linnaeus, 1758)	Gemsbok	8 496
Gemsbok (golden) Gemsbok (painted)			372 437 [3]
Giraffe	*Giraffacamelopardalis* (Linnaeus, 1758)	Giraffe	12 931
Greater kudu	*Tragelaphus strepsiceros* (Pallas, 1766)	Greater kudu	33 923
Greater kudu (white)			586 667
Grey rhebok (Vaalribbok)	*Pelea capreolus* (Forster, 1790)	Grey rhebok (Vaalribbok)	10 750
Impala	*Aepyceros melampus* (Lichtenstein, 1812)	Impala	8 643
Impala (black) Impala (black-backed) Impala (colour variant) Impala (split) Impala (white)			684 761[3]
Klipspringer	*Oreotragus oreotragus* (Zimmermann, 1783)	Klipspringer	22 063
Lechwe	*Kobus leche* (Gray, 1850)	Lechwe	67 758
Mountain zebra	*Equus zebra* (Linnaeus, 1758)	Mountain zebra	4 809
Nyala	*Tragelaphus angasii* (Gray, 1849)	Nyala	24 165
Oribi	*Ourebiaourebi* (Zimmermann, 1783)	Oribi	-
Plains zebra	*Equus quagga* (Gray, 1824)	Plains zebra	4 809
Red hartebeest	*Alcelaphus buselaphus* (Pallas, 1766)	Red hartebeest	7 462
Roan	*Hippotragus equinus* (Desmarest, 1804)	Roan	544 531
Sable	*Hippotragus niger* (Harris, 1838)	Sable	787 645
Southern reedbuck (Rietbok)	*Redunca arundinum* (Boddaert, 1785)	Southern reedbuck (Rietbok)	17 113
Springbok	*Antidorcas marsupialis* (Zimmermann, 1780)	Springbok	2 861
Springbok ("bont") Springbok (black) Springbok (coffee hartwater) Springbok (coffee) Springbok (copper) Springbok (hartwater)			210 872[3]
Steenbok	*Raphicerus campestris* (Thunberg, 1811)	Steenbok	29 887
Tsessebe	*Damaliscus lunatus* (Burchell, 1823)	Tsessebe	113 229
Waterbuck	*Kobus ellipsiprymnus* (Ogilby, 1833)	Waterbuck	5 991

[1] Bronner *et al*. (2003)

[2]Dr. Johann Reyneke (WildSA & Gamelab) & Dr. Paul Lubout (Wildlife Stud Services & Gamelab) December 2015

[3] The average price was calculated from all available data on colour variants of the species provided by Reyneke & Lubout