Population Dynamics and Relocation Success of the Oribi Antelope (*Ourebia ourebi*) in KwaZulu-Natal, South Africa

by

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COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

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Tamanna Patel

November 2015

Preface

The work described in this thesis was carried out at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa, from July 2013 to June 2015, under the supervision of Dr. Adrian M. Shrader, Dr. Ian T. Little (Endangered Wildlife Trust) and Dr. Keenan Stears.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, represents original work by the authors and has not been submitted in any form to another university. Where use of other work was made, it has been acknowledged in the document.

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"There are no secrets to success. It is the result of preparation, hard work, and learning from failure" – Colin Powell.

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Male oribi (*Ourebia ourebi*) at ZuluWaters Game Reserve

Abstract

In South Africa, oribi (*Ourebia ourebi*) antelope are listed as vulnerable. The lack of understanding of their population dynamics makes it difficult for oribi conservation. To address these gaps, I used the Oribi Working Groups' long-term survey database to determine 1) the trends (increasing, decreasing, stable) in oribi populations across KwaZulu-Natal, 2) the spatial distribution of these trends across the province, and 3) the factors influencing these trends. The overall oribi population trend for KwaZulu-Natal was linked with the number of survey returns submitted. This highlights the importance of landowners submitting consistent returns, resulting in more accurate population estimates. The majority of oribi populations across the province had decreasing population trends. I found that initial population size and the amount of suitable habitat available significantly affected oribi population growth rates. These growth rates increased when the availability of suitable habitat increased. In addition, grazing regime influenced growth rates. However, the variance observed was high, signifying that there may be other factors that are also responsible for driving these growth rates. Dog hunting was non-significant, however, because it is illegal, it was difficult to accurately measure its effect on oribi populations and thus should not be dismissed as a potential threat.

Relocating oribi has been used as a conservation tool over the past 16 years. However, the success of these relocations has been poorly documented. To address this, I determined 1) the success rate of previous oribi relocations in KwaZulu-Natal, 2) the factors driving the success/failure of the relocations, and 3) whether relocation is a successful tool for the conservation of oribi in South Africa. I found a relocation success rate of only 10% (N = 1). Moreover, I found that following basic relocation criteria (e.g. the removal of threats (such as predators) or long-term post-release monitoring) was important in assuring relocation success. In all instances where relocations failed, key criteria were not considered prior to the relocation. This was in contrast to the one successful relocation, where all the criteria were

considered and followed. Similar to my first study, I found that oribi population size, the availability of suitable habitat, and stocking rates of other large herbivores influenced growth rates, and ultimately, relocation success. Moreover, I found a significant interaction between suitable habitat available and stocking rates and their influence on population growth rates. Ultimately, this study highlights key factors that must be considered in any conservation or management decisions for oribi. In addition, prior to a relocation, landowners need to follow the basic criteria for successful relocations.

Keywords: *conservation, grazing regime, oribi population size, relocation success, stocking rate, suitable habitat*

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Thesis structure

Chapter 1 introduces the aims and objectives of the study. I then provide a Literature Review with an introduction to population dynamics and conservation biology. In addition, I discuss the different factors that influence herbivore population dynamics. I then discuss the numerous threats faced by oribi that has led to them being listed as vulnerable in South Africa.

Chapter 2 is written as a paper. In this chapter, I determine the population dynamics of oribi in KwaZulu-Natal, using the existing oribi database (2001 – 2014). This database was set up by the Oribi Working Group in order to monitor oribi population numbers across South Africa. Results highlight oribi populations in different areas in KwaZulu-Natal (both private and protected land) and indicates in which areas populations are increasing, decreasing, or remaining stable. In addition, I discuss the factors affecting these trends.

As with Chapter 2, Chapter 3 is also written as a paper. Relocation has been a key method used to conserve oribi – but how successful has it been? To address this question, I focused on key factors that have influenced the success of the previous ten oribi relocations that have taken place in KwaZulu-Natal over the past 16 years. I evaluate these relocations using the ten criteria generated by Pérez et al. (2012). Long-term post-release monitoring at most of these sites is severely lacking and more focus needs to be put into this aspect for future relocations.

Chapter 4 is a conclusion to the thesis as a whole and provides management recommendations for oribi populations and future relocations. In addition, limitations of the oribi database are discussed, as well as limitations of using questionnaires in research.

References are formatted according to the Journal of Ecology. The references cited in each chapter have been combined into a single reference list at the end of the thesis. I have done this to make it easier for examiners to check whether the in-text references are in the reference list, and reduce repetition between chapters. However, as the chapters are set out as individual papers, there is some degree of repetition.

Chapter 1

Introduction and Literature Review

Introduction

Oribi antelope (*Ourebia ourebi*) are grassland specialists. They require a combination of short and tall grass for feeding and cover from predators (Everett et al. 1991, Stears 2015). However, with increased demand for land to accommodate agriculture and forestry, oribi habitat is under threat (Everett 1991). In addition, illegal dog hunting has been identified as a major threat to this species (Magwaza and Little 2014). The combination of these threats has led to a decrease in oribi numbers in KwaZulu-Natal. Yet, the true extent and spatial distribution of this decline is unknown.

For species that are spread over a large range, but where individual populations are scattered across a number of different properties, questionnaires provide a valuable tool with which to obtain estimates of overall population change (Krebs 2009). As oribi antelope fit these criteria, questionnaires have been used to monitor population change in South Africa since the 1980's. For example, a study conducted in 1981 based on a random questionnaire survey estimated that the oribi antelope had disappeared from 23% of farms where they were known to have previously occurred (Marchant 2000). A follow up survey conducted by Ezemvelo KZN Wildlife in 1998 showed an overall declining trend in oribi numbers, with a 31% decline on the farms that had oribi in 1981, and a 25% reduction in the total oribi population (Marchant 2000). Although better monitoring is needed, the rate of decline in oribi population numbers has led them to be classified as endangered up until 2014 (Friedmann and Daly 2004), and vulnerable thereafter (Shrader et al. In press).

As the majority of oribi occur in small populations on farms rather than protected areas, farmers are key to ensuring the survival of oribi by protecting and managing habitats

(Everett 1991). However, the population dynamics of these oribi populations are poorly understood. In addition, the distribution of different oribi population trends within KwaZulu-Natal has not been clearly identified. To address these gaps, my MSc focusses on the following broad aim and objectives:

Broad aims:

To assess the population dynamics and status of oribi (*Ourebia ourebi*) in KwaZulu-Natal using the existing oribi database. In addition, to determine the success of relocation as a conservation tool for oribi in South Africa.

Objectives:

1. Determine whether oribi populations on both private and protected areas are increasing, decreasing, or remaining stable and how these populations are distributed throughout KwaZulu-Natal.
2. Explore the potential factors that could lead to populations increasing, decreasing, or remaining stable across the province.
3. Determine the success rate of previous oribi relocations in KwaZulu-Natal to assess whether this is a viable conservation tool for oribi.
4. Identify the factors that affect the success and failure of oribi relocations.
5. Provide recommendations to assist with future management of oribi populations and oribi relocations.

Motivation for research

In response to the findings by Marchant (2000), the Oribi Working Group (OWG) was formed in 2000 and a Committee was established in 2002 (McCann et al. 2006). This

Committee now consists of members from the Endangered Wildlife Trust (EWT), Ezemvelo KZN Wildlife (EKZNW), NCT Forestry, the University of KwaZulu-Natal, and private landowners. The OWG together with South Africa Community Action Network (SACAN) have been working consistently over the past 16 years in order to sustain and manage existing oribi populations and to try and reduce known threats to them (Magwaza and Little 2014).

The mission of the OWG is to promote the long term survival of oribi in their natural grassland habitat through initiating and co-ordinating Provincial conservation programmes (Magwaza and Little 2014). To monitor changes in oribi numbers, the OWG conducted oribi surveys biennially from 2001 to 2009 and then annually from 2010. These data comprise the OWG oribi database. However, assessments of individual oribi populations across South Africa, specifically KwaZulu-Natal, have not been conducted. Understanding the dynamic behaviour of populations and species distribution are important aspects in many conservation programmes and management decisions (Howard and Marchant 1984, Sinclair et al. 2006). Moreover, oribi relocations, as a conservation tool, have been used over the past 16 years, but the success rate of these relocations has been poorly documented. To help with future oribi conservation efforts, it was important to identify the different population trends and the factors driving them. Furthermore, the success or failure of relocations and the factors influencing success rate needed to be determined.

Literature Review

Section I: Population dynamics

The change in a population's size (i.e. increase or decrease) is influenced by fecundity rate, mortality rate, and dispersal (Sinclair et al. 2006, Krebs 2009). Moreover, immigration and emigration - the movement of individuals into and out of an area - are crucial factors when determining population changes (Bowler and Benton 2005). Dispersal results in gene flow between local populations, and it ultimately helps to prevent inbreeding (Krebs 2009). The speed of change in population size is measured as a rate of increase/decrease. Generally, populations fluctuate around a mean growth rate of zero, until conditions become more favourable or unfavourable, resulting in a population increase or decrease respectively (Lawton 1994).

Population growth

Natality, which is the production of new individuals, is a major component that increases population size. The fecundity rate of a population depends on the species breeding biology. Some species breed continually, some breed several times a year, and others breed once a year. Natality can be influenced by various environmental (abiotic) factors such as rainfall, which ultimately affects resources such as suitable habitat and food availability (Bennett and Saunders 2010).

Mortality

The number of individuals that leave a population is also an important component in population dynamics. Apart from dying from old age, individuals may die from disease (Pringle 2010) or they may die from a number of other natural causes (Krebs 2009). In addition, predation can affect the abundance and distribution of a population (Harrington et al. 1999, Boyce 2010). For example, the recovery of wolves (*Canis lupus*) in Yellowstone National Park has led to shifts in the distribution and abundance of elk (*Cervus elaphus*) (Boyce 2010).

Humans can also play a role in animal mortality. Animals are hunted for meat, hides and horns, and they are killed if they pose a threat to humans (Pringle 2010). For example, elephant (*Loxodonta africana*) poaching has been increasing in Africa because of the demand for ivory (Nishihara 2003, Douglas-Hamilton 2009). In addition, black rhinoceros (*Diceros bicornis*) and white rhinoceros (*Ceratotherium simum*) poaching in South Africa has been increasing drastically, negatively affecting many populations (Milner-Gulland and Leader-Williams 1992, Biggs et al. 2013). Many large-mammal populations in Africa have been extinguished by human alteration of ecosystems (i.e. habitat destruction) (Pringle 2010). Habitat destruction occurs when a natural habitat is damaged to the point where it can no longer support native species (Laurance 2010). This results in habitat loss and fragmentation. Habitat loss is a reduction in the amount of original habitat, whereas fragmentation is the subdivision of continuous habitat into distinct smaller patches (Wilcrove et al. 1986, Bennett and Saunders 2010). Moreover, fragmentation may result in a loss of habitat heterogeneity (Wilcrove et al. 1986). Different species respond differently to habitat fragmentation. Agriculture is the biggest cause of habitat destruction globally (Laurance 2010). However, urban development, forestry and mining also play a role.

Section II: Conservation of threatened species

The main focus of conservation biology is to understand and protect biological diversity (Meine 2010). Many threatened species that are in need of conservation are found in small and isolated populations. Populations may become small and isolated due to habitat loss and fragmentation. Ultimately, these small populations are more vulnerable to stochastic processes than larger ones (Bennett and Saunders 2010). Stochastic processes that can affect small populations include loss of genetic variation caused by inbreeding or genetic drift (Bennett and Saunders 2010). In addition, catastrophic events such as flood, fire, and drought and environmental fluctuations such as rainfall and availability of food sources can affect birth and death rates (Bennett and Saunders 2010). For example, tsessebe antelope (*Damaliscus lunatus lunatus*) suffered a population decline in the Kruger National Park

(KNP) due to changes in rainfall that ultimately affected dry season food availability (Dunham et al. 2004).

Small populations are generally more susceptible to change (increase and decrease) than larger populations (Bennett and Saunders 2010). They have a higher risk of going extinct because of demographic stochasticity and genetic drift causing a reduction of genetic diversity within a population (Lawton 1994). Larger populations also have a lower probability of inbreeding compared to smaller, fragmented populations (Lawton 1994). Although they are vulnerable to change, small populations have a higher chance of persistence if individuals are able to disperse between local populations (Bennett and Saunders 2010). The combination of these subdivided populations is known as a metapopulation. To protect a metapopulation, it is important to protect and expand the amount of suitable habitat, improve the quality of habitats, increase landscape connectivity, and manage disturbance processes (Bennett and Saunders 2010). In addition, it is important to learn from conservation actions already undertaken as this will help and improve future actions (Bennett and Saunders 2010).

The term 'minimum viable population' (MVP) suggests that there is some threshold for the number of individuals that can persist in a viable state over a period of time (Gilpin and Soulé 1986). Population size determines the persistence in animal populations (Reed et al. 2003). However, there is no single MVP size that is applicable to all species; it will vary among species and among populations within species (Traill et al. 2007). Moreover, an MVP size will depend on the life history of the population, the temporal and spatial distribution of resources, and the level of genetic variation (Gilpin and Soulé 1986). Population viability analysis (PVA) is a quantitative mean for determining the probability of extinction (Reed et al. 2003). PVA's often aid with making management decisions of endangered species (Beissinger and Westphal 1998).

Before any conservation practices can be put into place, it is important to identify the cause of decline of a population and whether it is due to a single factor or combination of factors (Brambell 1977). Until the threats have been identified and removed, a species cannot be protected. There are many ways of conserving different species. For example, legislative changes such as a ban on hunting can be effective (Leader-Williams and Milner-Gulland 1993). Most of the time, however, active management is required. This involves practices such as regulation of harvest, predator control, the establishment of corridors, captive breeding, and/or relocations (Sinclair et al. 2006). Moreover, protected areas (e.g. reserves or national parks) and community conservation play a key role in the protection of threatened species.

Relocation is the deliberate movement of an animal or population of animals from an area where they are threatened, to a more suitable habitat comprising fewer threats (Dodd and Seigel 1991). The new area should generally be a habitat where the animal historically occurred, however, this is not always the case (Dodd and Seigel 1991). Relocation is a popular and commonly used tool for the conservation of different species (Fischer and Lindenmayer 2000). There have been many successful relocations that have helped conserve a range of species (Pienaar 1970, Penzhorn 1971, Spalton et al. 1999). For example, the relocation of eland (*Taurotragus oryx*) and red hartebeest (*Alcelaphus buselaphus caama*) to Addo Elephant National Park was so successful that these populations later served as a source for re-introductions into other national parks (Penzhorn 1971). Relocations therefore have a proven track record as a successful conservation tool for a wide range of mammalian herbivores.

Section III: Oribi (*Ourebia ourebi*) conservation

Population status

The global status of oribi is Least Concern (IUCN 2008). However in South Africa, oribi were previously classified as endangered (Friedmann and Daly 2004). Currently, their red list status is being down listed to vulnerable (Shrader et al. In press).

Distribution

Oribi antelope are distributed widely throughout the African continent from Senegal to Ethiopia and south to the Eastern Cape Province of South Africa (Smithers 1983). However, this distribution is patchy and discontinuous (Estes 1991), largely due to the fact that oribi have very specific habitat requirements (i.e. long grass for cover and short grass for feeding) (Smithers 1983, Adamczak and Dunbar 2007). They exist in temperate montane and tropical Africa and are primarily grassland residents (Tinley 1969, Pienaar 1974). In South Africa, oribi are found in Mpumalanga, Gauteng, the North West, Free State, KwaZulu-Natal and the Eastern Cape (Friedmann and Daly 2004). Core populations are in Mpumalanga, KwaZulu-Natal and the Eastern Cape. In KwaZulu-Natal, they are found mainly in the interior of the province in isolated populations throughout the grasslands (Howard and Marchant 1984, Everett et al. 1991), mainly on privately owned land and within certain protected areas (Coverdale et al. 2006). Their distribution throughout this range is patchy and discontinuous (Figure 1.1), yet the historical distribution is likely to have been less fragmented than at present (Rowe-Rowe 1994).

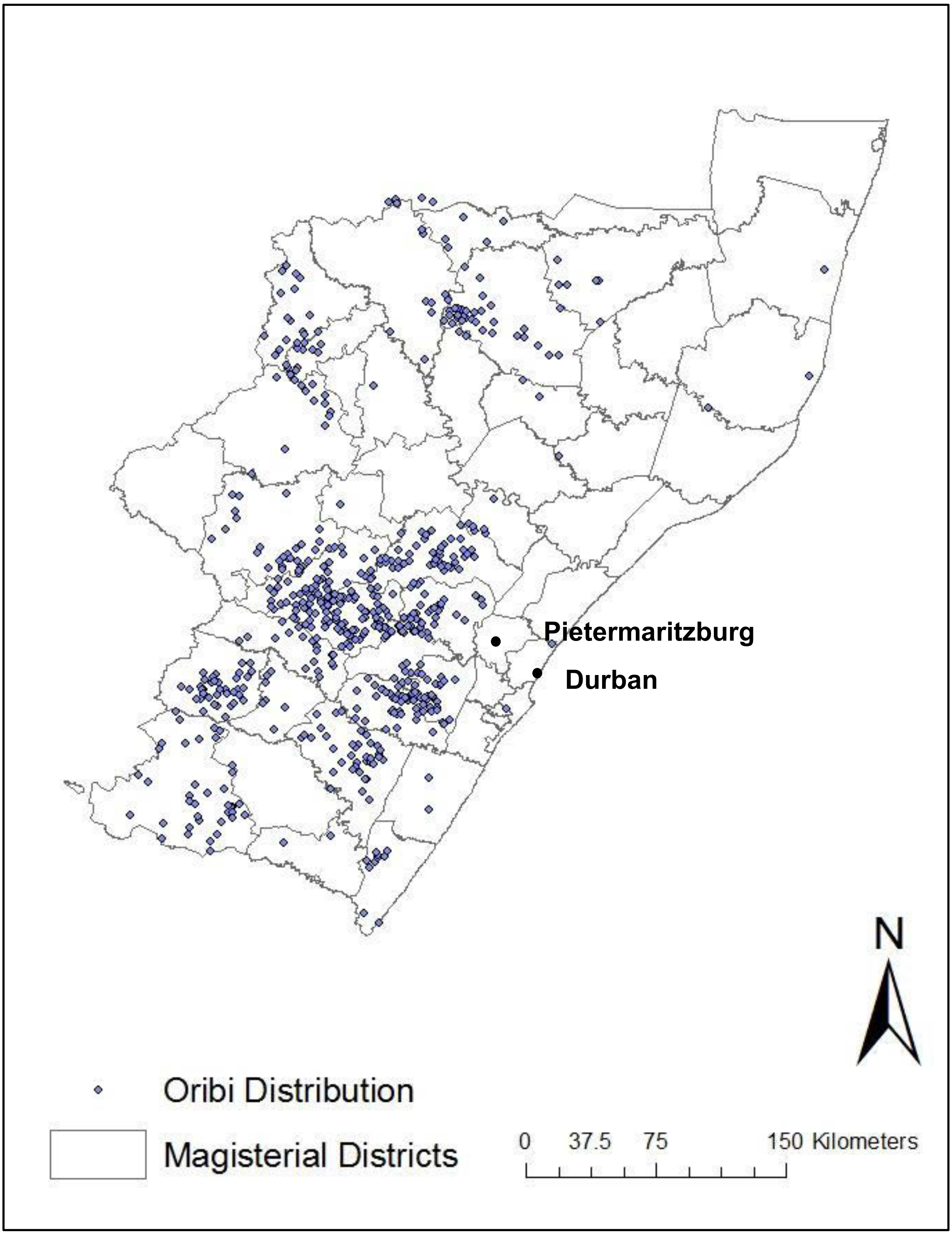

Figure 1.1: Oribi population distribution in KwaZulu-Natal, South Africa. Map shows KZN Magisterial Districts. Data obtained from the Oribi Working Group.

Habitat requirements: foraging and reproduction

Oribi are Africa's smallest pure grazing antelope. The rams have an average mass of 14 kg and the ewes 16 kg (Reilly 1989, Jongejan et al. 1991, Adamczak 1999). They occupy open and wooded grasslands (Coverdale et al. 2006), and avoid bushland and woodlands (Smithers 1983, Estes 1991, Adamczak and Dunbar 2007). Being highly specialised species, they require both short and tall grass for feeding, but also use tall grass for cover against predators and concealment of their young (Smithers 1983, Everett et al. 1991). Due to their small body size, oribi are selective feeders, preferring specific grass species (e.g. *Themeda triandra*) and grass parts (e.g. green leaves) (Coverdale et al. 2006, Stears 2015). In addition, oribi tend to prefer areas that have been recently mowed or burnt, as the grass in these areas have a tendency to be high in protein and energy, and low in fibre (Everett et al. 1991).

Due to the high metabolic demands associated with their small body size (Bell 1971, Jarman 1974, Stears 2015), oribi are under immense pressure with regard to having to feed on high quality food (Adamczak and Dunbar 2007). As a result, it is important that habitat is well managed such that it remains in good condition (i.e. it contains high quality grass species) - if it is to accommodate high oribi numbers. Everett et al. (1991) found that the best way to maintain both of these factors was a combination of biennial spring burning, mowing/grazing and wide firebreaks during autumn and winter. Burning can create mosaics of different patch sizes of regenerating vegetation (Bowman and Murphy 2010). This will ultimately provide oribi with the resources and shelter that they require.

Within these grassland habitats, oribi establish home ranges/territories that vary from 28 ha (in the Transvaal) (Viljoen 1975) to 60 ha (in Natal) (Everett 1991). Within the Drakensberg Park, KwaZulu-Natal, the mean home range size was found to be ~49 ha (Oliver et al. 1978). Food availability and total population size of a given area play an important role in determining the home range size required by oribi. Home ranges for oribi are normally large and include peripheral areas not generally used by that individual (Everett 1991). The density of oribi in an area is linked to factors such as abundance of space, and rainfall, which in turn is linked to the quality and quantity of forage (Brashares and Arcese 2002). Oribi densities depend on the quality of the habitat and how it is managed (Oliver et al. 1978, Everett 1991, Rowe-Rowe 1994). Oribi density is important in influencing population growth rates, as this can lead to stable populations (Tanner 1966).

In order to reproduce, animals need to generate sufficient energy reserves. Suitable habitat not only allows oribi to obtain this energy, it also provides areas in which oribi can hide their young, which are left to lie out for the first eight to ten weeks (Rowe-Rowe 1994). Therefore, suitable habitat plays a key role in influencing reproduction and survival of offspring. If correct habitat requirements are not met, individuals will likely experience lower reproductive success and the population will decline.

Threats

Oribi are a threatened species in South Africa. Currently, their classification is being down listed to vulnerable (Shrader et al. In press). There are, however, many threats that affect the survival of oribi in their natural habitats. Habitat destruction via human development is considered the main cause of previous declines in oribi numbers (Thompson 1973, Marchant 1991). Across much of their historic range, grasslands have been converted for afforestation, agricultural crops, pastures, sugar cane and timber (Smithers 1983, Shrader et al. In press). In addition, inappropriate management of these grasslands also threatens oribi populations (Coverdale et al. 2006, Stears 2015). This includes overstocking with large mammalian herbivores (i.e. livestock and/or wildlife), and incorrect grazing and burning regimes, which results in grassland degradation (Shrader et al. In press). For example, in the Eastern Cape province, habitat destruction due to intensive farming and the fact that land was being populated and converted by small-scale farmers were the main factors that caused the decline in oribi numbers (Millar 1970). Lack of government policies and implementation (i.e. poor enforcement of environmental legislature) and the lack of overall management (e.g. poor burning practices) also plays a role in threatening the survival of oribi (Coverdale et al. 2006).

Grassland habitats are vital for the survival of oribi, as these antelope are grassland specialists and cannot survive elsewhere. As a result, oribi act as a flagship species of indigenous grasslands (Shrader et al. In press). They prefer grasslands dominated by *T. triandra*, which is a valuable veld grass and an indicator of good quality veld (Coverdale et al. 2006). In South Africa, 60% of grasslands have already been irreversibly transformed, and only 2.4% are formally conserved (Carbutt and Martindale 2014). It is therefore important to conserve the remaining grassland to prevent further habitat loss and fragmentation.

Another threat to oribi is poaching and illegal hunting with dogs (Viljoen 1982, Smithers 1983, Shrader et al. In press). This is a serious threat to the survival of the species and has led to declines in oribi populations in the KwaZulu-Natal midlands (Everett 1991, Marchant 1991). Illegal hunting is mostly done using packs of dogs. However, trapping of animals with snares for bush meat also takes place. There has been a drastic increase (i.e. 30 to 113) in the reported number of illegal dog hunting incidents from 2012 to 2013 (Magwaza and Little 2014). Added to normal subsistence hunting is the rise of 'taxi hunts' which is a popular form of sport betting in KwaZulu-Natal (Little and Magwaza 2013). This involves large groups of hunters with their packs of dogs. Hunters trespass onto private land, release their dogs and then gamble on which dog will make the first kill (Little and Magwaza 2013).

Natural causes such as predation and diseases (Thompson 1973) are also factors causing the decline of oribi numbers. They are preyed upon by jackal (*Canis mesomelas*), caracal (*Caracal caracal*), and serval (*Leptailarus serval*) (Brashares and Arcese 2002).

When a predator is sighted, oribi instinctively sink to the ground and hide (Adamczak 1999). If spotted, their last option is to run, which makes them vulnerable to predators. Oribi are also illegally traded. They are captured and moved illegally due to the high prices paid for live individuals at game auctions (Coverdale et al. 2006). This is encouraging some landowners to sell their animals, as opposed to conserving them on their lands (Rowe-Rowe 1994, Coverdale et al. 2006). As a result of these threats, appropriate management and protection plans need to be implemented. In addition, public awareness around these issues needs to be expanded.

One of the greatest challenges with regard to oribi conservation is that it is difficult to accurately estimate oribi numbers, because of their small size and the fact that they spend a large proportion of their day lying in long grass (Marchant 1991). The difficulty in obtaining accurate oribi numbers results in apparent population fluctuations between years. As a result, it is difficult to assess long-term population trends. Because oribi are predominantly found on privately owned land (Coverdale et al. 2006), a key way to estimate numbers is by using surveys and questionnaires (Millar 1970, Thompson 1973, Howard and Marchant 1984, Munn and Drever 1990). Surveys have been conducted over the past 13 years to keep up to date with oribi numbers in South Africa. Here, it is up to the farmer to supply oribi numbers, which are often done infrequently. Within protected areas, conservation agencies conduct survey counts to determine oribi numbers and their distribution.

Because of the many threats, there is a strong need to try to conserve the remaining oribi populations. In an attempt to do this, there have been a number of conservation strategies set up for oribi. These include establishing oribi conservation area networks, minimising habitat loss by influencing development and activities within suitable oribi habitats, developing awareness campaigns, incentives for landowners (custodian programme), effective law enforcement processes, research and monitoring of current oribi populations, captive breeding and relocation programmes (Coverdale et al. 2006). Because oribi populations are widely spaced, there is very little to no natural immigration and emigration. For this reason, relocation has been seen as a key option for oribi. Oribi relocations have been occurring for the past 16 years, however, the success rate of these relocations has been poorly documented. Thus, the success of this tool for the conservation of oribi is unknown.

Chapter 2

Population dynamics of oribi antelope (*Ourebia ourebi*) in KwaZulu-Natal, South Africa

In South Africa, oribi antelope (*Ourebia ourebi*) are currently listed as vulnerable. However, one factor that hampers conservation efforts is a lack of understanding of their population dynamics. To address this, I focused on long-term population data for KwaZulu-Natal obtained from the Oribi Working Groups (OWG) oribi survey database. These data allowed me to determine 1) the trends (increasing, decreasing, stable) of individual populations across KwaZulu-Natal, 2) the spatial distribution of these trends across the province, and 3) the factors driving these population trends. Results indicate that more accurate population estimates were obtained when more survey forms were returned (i.e. more data). This emphasized the need for landowners that have oribi on their properties to consistently submit annual returns. In addition, I explored whether land type (private/protected), initial oribi population size, the amount of suitable habitat available (e.g. grasslands), and/or grazing regime (continuous/rotational) influenced population trends and growth rates. I found that initial population size had a significant effect on growth rates. However, there was a high variance in growth rates around small population sizes. In addition, growth rates increased when the availability of suitable habitat was >600 ha. With regard to grazing regime, population growth rates on both rotational and continuous grazing systems decreased as initial population size decreased. In contrast, these growth rates increased as the availability of suitable habitat increased. However, the variance observed was high, indicating that some other factor is likely affecting these growth rates. Dog hunting was non-significant, however, because of its illegal nature, it is difficult to obtain accurate measurements of its effect on oribi populations. Therefore, it should not be dismissed as a potential threat. Ultimately,

initial oribi population size, amount of suitable habitat available, and grazing regime were important factors that helped determine the population dynamics of oribi.

***Keywords**: conservation, continuous grazing, initial population size, rotational grazing, suitable habitat*

Introduction

Stable populations of animals fluctuate around a mean growth rate of zero (Sinclair et al. 2006, Krebs 2009). However, when conditions change (i.e. become more favourable or unfavourable), populations will either increase or decrease respectively (Sinclair et al. 2006). Understanding the dynamic behaviour of a population is important in many conservation and management decisions (Sinclair et al. 2006). Moreover, identifying which factors drive animal population dynamics is essential in determining how to manage them (Gordon et al. 2004).

Many factors can cause populations to increase or decrease. Population size is an important factor when dealing with the conservation of a species (Lynch et al. 1995). Both fecundity and mortality can be influenced by population size. Larger populations have a lower inbreeding and extinction risk than smaller, fragmented populations (Lawton 1994, Lynch et al. 1995) and could potentially have greater growth rates (Lynch et al. 1995). However, large populations may have stable growth because they are limited by resources (i.e. density dependence), intraspecific and/or interspecific competition (Kutsukake 2009). Small populations are more susceptible to change (increase and decrease) than larger ones (Bennett and Saunders 2010) due to greater susceptibility to stochastic events such as demographic stochasticity (e.g. variation in reproduction and mortality of individuals) or environmental stochasticity (e.g. variation in weather, food supply, predators, competitors) (Keller and Waller 2002).

Alternatively, small populations have the ability to display increasing growth rates because of the greater availability of resources (e.g. suitable habitat for food, shelter, and reproduction) due to lack of competition (Bowyer et al. 2014). Therefore, small populations can continue to grow until they reach carrying capacity. Ultimately, the population dynamics of any species will be affected by intraspecific competition, especially as carrying capacity declines, intraspecific competition increases.

A second factor that can influence population growth is the amount of suitable habitat available. If suitable habitat is plentiful, there may be enough resources to prevent competition (Bowyer et al. 2014). However, habitat loss and fragmentation are threats to many species because they reduce the amount of suitable habitat available to individuals and territorial groups (Wilcrove et al. 1986, Bennett and Saunders 2010). Therefore, if suitable habitat is limited, competition between individuals/species will likely increase (Bowyer et al. 2014) and this can ultimately reduce population sizes. For example, competition from cattle led to a reduction in tsessebe antelope (*Damaliscus lunatus lunatus*) numbers on a cattle ranch in Zimbabwe (Dunham et al. 2003). Individuals within a population may also compete for limited resources (e.g. food, space). For example, blackbuck (*Antilope cervicapra*) compete for food when they are found in larger groups (Isvaran 2007).

Apart from habitat loss and fragmentation, the availability of suitable habitat can be influenced by management practices such as stocking rates (Stears 2015), burning and grazing regimes (Teague and Dowhower 2003). For example, Stears (2015) found that at high stocking rates, intense grazing by cattle reduced the amount of high quality grass available for oribi (*Ourebia ourebi*) during both the wet and dry seasons. Furthermore, management may vary according to whether populations are found on private (cattle or crop farms) or protected land (conservation areas). In addition, the different grazing regimes used by management (rotational or continuous) could ultimately influence population trends. A number of studies have shown that different grazing regimes influence habitats by affecting heterogeneity (Gammon 1978, O'Reagain and Turner 1992, Derner et al. 1994, Teague and Dowhower 2003). As habitat heterogeneity influences the amount of suitable habitat available, grazing regimes can ultimately impact herbivore population numbers.

A third key factor that can affect herbivore populations is mortality, and in this case, human induced mortality through poaching. For example, black rhinoceros (*Diceros bicornis*), white rhinoceros (*Ceratotherium simum*) and elephant (*Loxodonta africana*) poaching in Africa has been increasing drastically over the past 25 years, negatively affecting many populations (Milner-Gulland and Leader-Williams 1992, Nishihara 2003, Douglas-Hamilton 2009, Biggs et al. 2013). Furthermore, saiga antelope (*Saiga tatarica*) of central Asia are under severe threat from poaching for their meat and horns, which has resulted in population declines (Milner-Gulland et al. 2001). However, poaching also works in conjunction with natural forms of mortality such as disease or predation. For example, the reduction in saiga population was also due in part to an increase in predation pressure from wolves (Milner-Gulland et al. 2001). Previously wolves were shot to protect livestock and siaga. However, they are now increasing throughout the saiga's range (Milner-Gulland et al. 2001). As a result, it seems likely that the combined mortality from poaching and wolves were the key factors reducing saiga numbers.

In South Africa, the oribi is the most threatened antelope species (Friedmann and Daly 2004, Shrader et al. In press). A key challenge with regards to understanding the population dynamics of this threatened antelope is obtaining reliable long-term data. One way to obtain these data is to use questionnaires (Krebs 2009). An initial population assessment showed that oribi had disappeared from 23% of the farms where they previously occurred (Marchant 2000). Together with an increase in land-use that led to the fragmented distribution of oribi, the status of oribi within KwaZulu-Natal became a concern. This led to a follow up survey conducted by Ezemvelo KZN Wildlife (EKZNW) in 1998. Results from this survey showed an overall declining trend in oribi numbers, with a 31% decline in the number of farms that had oribi in 1981, and a 25% reduction in the total oribi population (Marchant 2000). One of the key challenges facing the conservation of oribi is that their population dynamics in South Africa are poorly understood (Shrader et al. In press). As a result, this leads to uncertainty in the overall trends of oribi populations across the country. Moreover, there is little information on what may be driving these trends.

Oribi are highly specialised antelope. They require grasslands with a degree of heterogeneity consisting of short grass areas for feeding and tall grass for feeding, cover against predators and concealment of young (Smithers 1983, Everett et al. 1991, Rowe-Rowe 1994). As the amount of suitable habitat available can affect whether a population increases or decreases (Bowyer et al. 2014), it is important to understand how the availability of suitable habitat influences oribi population dynamics. Because oribi are small selective feeders, they need to ingest high quality food (Stears 2015). Suitable habitat comprising heterogeneity in grass height allows oribi to obtain enough high quality food (Stears 2015). Therefore, a mosaic of suitable habitat is essential for oribi as it influences their foraging, reproduction and survival of offspring.

One other factor that poses a threat to oribi populations in South Africa is poaching primarily in the form of illegal hunting with dogs (Viljoen 1982, Smithers 1983, Everett 1991, Marchant 1991, Shrader et al. In press). From 2008 – 2012, there has been an increase in the number of dog hunting incidents (Little and Magwaza 2013). A disturbing factor fuelling this increase is that a large portion of poaching is through what is termed taxi hunting. Taxi hunting is a popular form of sport-gambling in KwaZulu-Natal where a large number of people and dogs illegally hunt on private land and gamble on which dogs will make the first kill (Little and Magwaza 2013). However, because it is illegal, the level of impact of dog hunting on individual oribi populations is difficult to quantify.

As little is known about the population dynamics of the oribi population in South Africa, I focused my study on the long-term population trends and how these trends varied across private and protected areas. Moreover, as a majority of the oribi are found in

KwaZulu-Natal, I restricted my study to the oribi populations in that province. In addition, I attempted to identify the key factors that drive long-term oribi population trends. These included land management type (private vs. protected), initial population size, availability of suitable habitat, grazing regime (i.e. continuous vs. rotational), and poaching pressure.

Wildlife density is generally higher on protected lands as populations can be determined by ecological carrying capacity, which leads to higher levels of competition. In contrast, on private lands, livestock tend to be kept at a lower density driven by economic carrying capacity, which can result in low levels of competition (Sandland and Jones 1975). Because management practices (e.g. grazing regime) in these areas can influence many factors driving population trends, I predicted that oribi population growth would be higher on private farms compared to protected lands. Secondly, as small populations are more susceptible to perturbations compared to larger populations (Lawton 1994, Lynch et al. 1995), I predicted that the majority of small populations would be decreasing. In contrast, if these small populations had access to sufficient resources, then I predicted that they would be increasing.

The third factor I focussed on was the availability of suitable habitat (i.e. the availability of both short and long grass areas). I predicted that oribi populations with access to suitable habitat would increase, while those that had limited access would decline. My fourth hypothesis was that grazing regime would influence oribi population trends. Specifically, I predicted that continuous grazing (i.e. animals remain in the same area throughout the year) would be better for promoting habitat heterogeneity (i.e. grass height), which is vital for feeding and reproduction of oribi (Smithers 1983, Everett et al. 1991, Stears 2015). This is because rotational grazing (i.e. movement of animals between different camps) results in a more even use of the landscape compared to continuous grazing (O'Reagain and Turner 1992), ultimately reducing grass heterogeneity. Finally, I predicted that illegal dog hunting would decrease population growth because of its direct removal of oribi. As many of these factors work in conjunction, it is likely that a combination of some of these factors together will influence any given population trend.

Methods

Oribi database

In response to Marchant (2000), the Endangered Wildlife Trust (EWT) together with Ezemvelo KZN Wildlife, representatives from the forestry industry (e.g. NCT, Mondi and Sappi), and the University of KwaZulu-Natal formed the Oribi Working Group (OWG). Because a majority of oribi populations occur on private lands, one of the key tasks of the OWG is to conduct oribi surveys (see survey form in Appendix 1) to collect population data. These OWG surveys started in 2001 and were conducted biennially until 2009. Then, starting in 2010, the surveys were conducted annually. Oribi counts are conducted from September to November each year because oribi tend to concentrate their feeding on the green flush growing on areas that are burnt in September (Magwaza and Little 2014). As a result, they are generally easier to see and thus more accurate population estimates can be obtained (Magwaza and Little 2014). In addition to the number of individuals counted, landowners are asked to provide information on the oribi population dynamics found on their property (e.g. age, sex, population trend), the perceived threats to their oribi population, and property details. However, not all landowners provide all this information, thus some of these data are missing for some of the sites. Once the surveys are returned, data are entered into a database. As a result, this database contains oribi population information from 2001 to present. For my study, I restricted my focus to the populations within KwaZulu-Natal as these data were the most complete, and the majority of oribi are found within this province.

To get a clear understanding of the distribution of oribi in KwaZulu-Natal, I first plotted the location of all the sites (N = 589) geographically using ArcMap 10 (Figure 1.1). Then, to determine the overall oribi population trend in KwaZulu-Natal, I plotted oribi numbers from 2001 to 2014 and fitted a linear trend line (Figure 2.1). Due to the low overall r^2 value (see Results), I examined individual populations to determine trends at a site level.

Selection of sites

I was unable to calculate oribi population trends using all sites in KwaZulu-Natal (N = 589) because a large number of these sites did not regularly submit returns and thus annual population estimates were missing. Thus, to increase the accuracy of the population trend estimates, I limited my analyses to sites that had submitted three or more returns (N = 100 sites; private land: N = 74; protected land: N = 26) over the 13 years that the surveys had been conducted. The time series of the survey returns varied from site to site over the 13 years, however, this allowed me to generate population trends (see below). Because oribi numbers are calculated from survey returns, I ran a regression analysis to determine if oribi population size was related to the number of survey returns for both private and protected areas (see Figure 2.2 in the Results). I then plotted the selected sites on a map to determine how they were distributed throughout KwaZulu-Natal (see Figure 2.4 in the Results).

I then determined population trends for each of the sites and separated locations based on whether they were private or protected areas. I fitted trend lines to these data to determine whether each population (N = 100 populations) was increasing, decreasing, or stable. To support the trend with values, I calculated the finite rate of increase of a population (population growth rate), termed lambda (λ) (i.e. the ratio of population size at one time to its size one time-unit earlier). There are other methods to assess population trends (e.g. generalized θ-logistic population growth model; McMahon et al. 2009). However, this model was not used as it is unreliable for modelling most census data and is sensitive to temporal variation in carrying capacity (Clark et al. 2010). Therefore, I used lambda as it can be generated from population counts at successive times, even without knowing per capita birth and death rates (Stratton 2010). Lambda is a useful approach to assess the health of a population over a period of study (Nichols and Hines 2002). In addition, it can be calculated between any two years of population data (Hone 2014), which was useful with the data I had from the OWG database. When $0 < \lambda < 1$, the population growth was considered decreasing. When $\lambda = 1$, the population growth was considered stable, and when $\lambda > 1$, the population growth was considered to be increasing (Stratton 2010, Hone 2014). After determining the percentage of the 100 populations for both private and protected areas that were increasing, decreasing, and remaining stable (Figure 2.4), I plotted the spatial distribution of these trends across KwaZulu-Natal (Figure 2.5).

Factors influencing oribi population growth

Following the population trend analysis, I then explored the factors that influenced these trends. To do this, I contacted as many of the landowners of the selected sites as possible, and conducted a structured survey about their property and oribi populations (see Appendix 2). However, many of the contact details were outdated or absent in the database, thus I was only able to obtain information from 25 sites (private land: N = 17; protected land: N = 8).

For each of these sites, I identified potential variables that could explain the observed oribi population trends (i.e. λ). These included land type (private land or protected conservation areas), initial oribi population size (population size when the first survey form was submitted), amount of suitable habitat available (in hectares), grazing regime (continuous/rotational), and dog hunting. Initial population size was included as a variable because oribi are generally found in small, fragmented populations (Everett 1991).

Furthermore, small populations have more scope for population growth because resources are less limited (Bowyer et al. 2014), unless the available habitat is equally small. The different grazing regimes (as defined per farm/reserve) by domestic livestock/wild herbivores affects habitat heterogeneity and may influence the amount of suitable habitat available at each site. For the purpose of this study, rotational grazing per farm/reserve was defined as the movement of animals between different camps throughout the year, whereas continuous grazing sites did not utilise camps, but rather allowed animals to free forage within the whole area throughout the year. The amount of suitable habitat available could potentially influence foraging and reproduction, as well as predation risk (Smithers 1983, Everett et al. 1991, Stears 2015). For this study, suitable habitat was defined as an availability of a heterogeneous mix of both short and tall grass areas. It was assessed by asking landowners to estimate how much grassland they had within their property. Furthermore, within this grassland, how much was suitable oribi habitat (i.e. had short and long grass areas) (see Appendix 2). Therefore, the suitable habitat available for oribi to utilise was a portion of the total site area. Illegal dog hunting is important because it is a major direct threat to oribi (Viljoen 1982, Smithers 1983, Everett 1991, Marchant 1991, Shrader et al. In press). For this analysis, I included the presence or absence of dog hunting at each site. Because of its illegal nature, it was not possible to quantify the effects of dog hunting on oribi population growth.

Statistical analysis

<u>Factors influencing oribi population growth</u>

To determine if oribi population growth rates differed in private and protected conservation areas, I ran a Generalized Linear Model (Gamma distribution and log link function) (GLM) (Model 1). For this analysis, I used λ as the dependent variable and land type (private or protected) as the independent variable (private land: $N = 17$; protected land: $N = 8$). Because the initial oribi population size and the availability of suitable habitat for oribi could influence population growth rates, I included these factors as covariates in the model. There were no significant differences between λ values for private and protected lands (see Results). As a result, these data were pooled and further statistical analyses performed on the pooled data.

First, I wanted to determine if initial population size and the availability of suitable habitat for oribi influenced population growth rates (i.e. λ: N = 25 sites). To do this, I used a GLM (Model 2) with λ as the dependent variable. Initial oribi population size, the availability of suitable habitat and their interaction were included as independent variables. To assess whether grazing regime influenced oribi population growth, I ran two additional GLMs (Models 3 and 4 respectively). First, I included grazing regime (continuous grazing: N = 15; rotational grazing: N = 10) and initial oribi population size as main factors. In addition, I included the interaction effect (grazing regime x initial oribi population size) and the amount of suitable habitat available as a covariate. In the second model, I included grazing regime and the availability of suitable habitat as main factors. In addition, I included the interaction effect (grazing regime x amount of suitable habitat available) and initial oribi population size as a covariate. The reason I included these covariates was that I found that they significantly influenced oribi population growth rates (see Results). As a result, by incorporating the availability of suitable habitat as a covariate in model 3, I took into account its' effect when testing for the interaction between grazing regime and initial population size and their influence on oribi population growth rates. Similarly, by including initial population size as a covariate in model 4, the effect of this variable was controlled for.

Finally, to determine if illegal dog hunting influenced oribi population growth rates, I ran a GLM (Model 5). For this analysis, I used λ as the dependent variable and dog hunting (yes or no) as the independent variable (yes: N = 24; no: N = 1). Initial oribi population size and the availability of suitable habitat for oribi could influence population growth rates, so I included these factors as covariates in the model. All statistical analyses were conducted using IBM SPSS Statistics 21.

Results

The annual oribi survey found that the total oribi population in South Africa (N = 3006 individuals in 2014) is higher than what was previously thought (N = 2574 individuals in 2012; N = 2932 in 2013). This result has led to oribi being down listed in South Africa from endangered to vulnerable (see Shrader et al. In press). Overall, the oribi population across KwaZulu-Natal showed a decreasing trend in population size from 2001 to 2014, ranging from 1048 to 2285 individuals (Figure 2.1). However, this decrease was gradual ($r^2 = 0.172$) (Figure 2.1). Population fluctuations across the years was a result of the strong correlation between the number of survey forms returned each year (Figure 2.2). Thus, population estimates only represent a minimum population size.

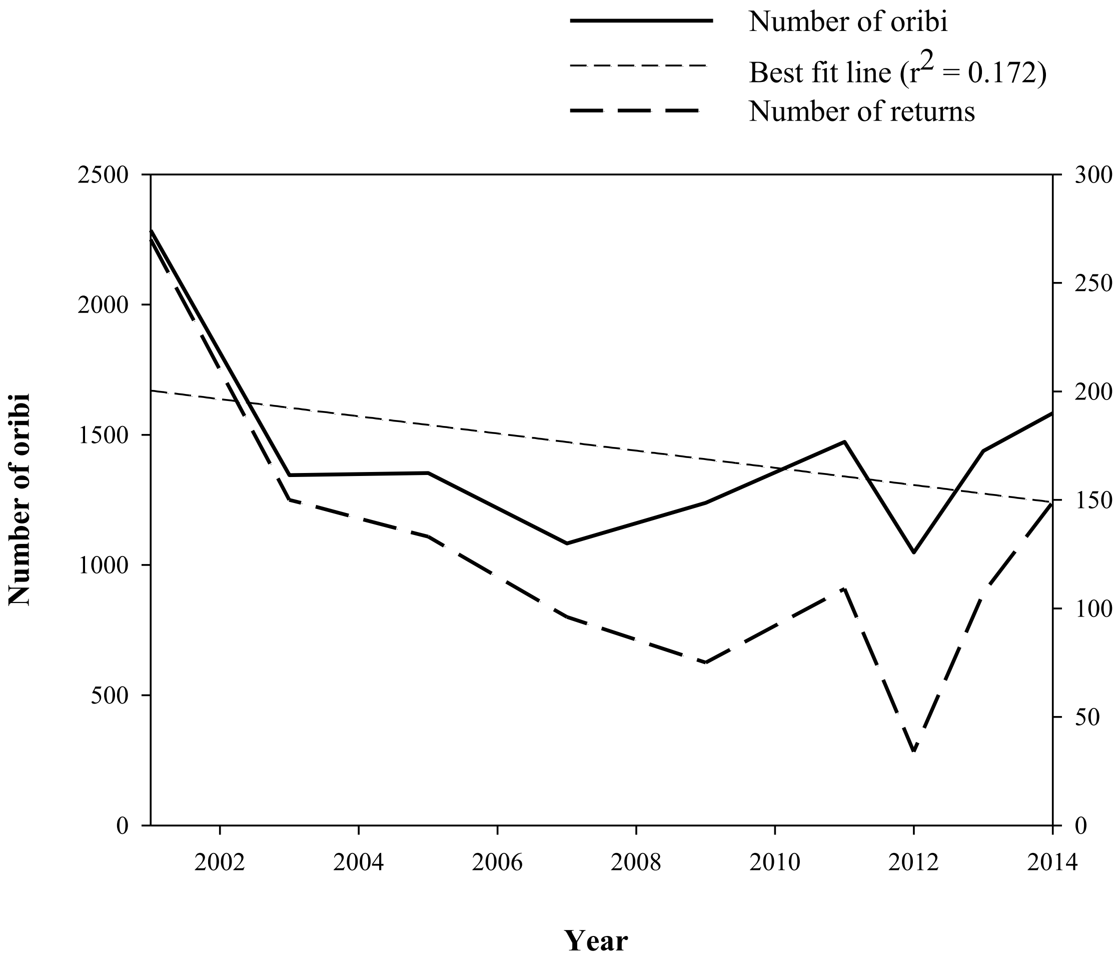

Figure 2.1: Oribi population trend and number of surveys returned across KwaZulu-Natal from 2001 to 2014 for both private and protected areas (N = 589 sites). Data obtained from the Oribi Working Group.

(a) (b)

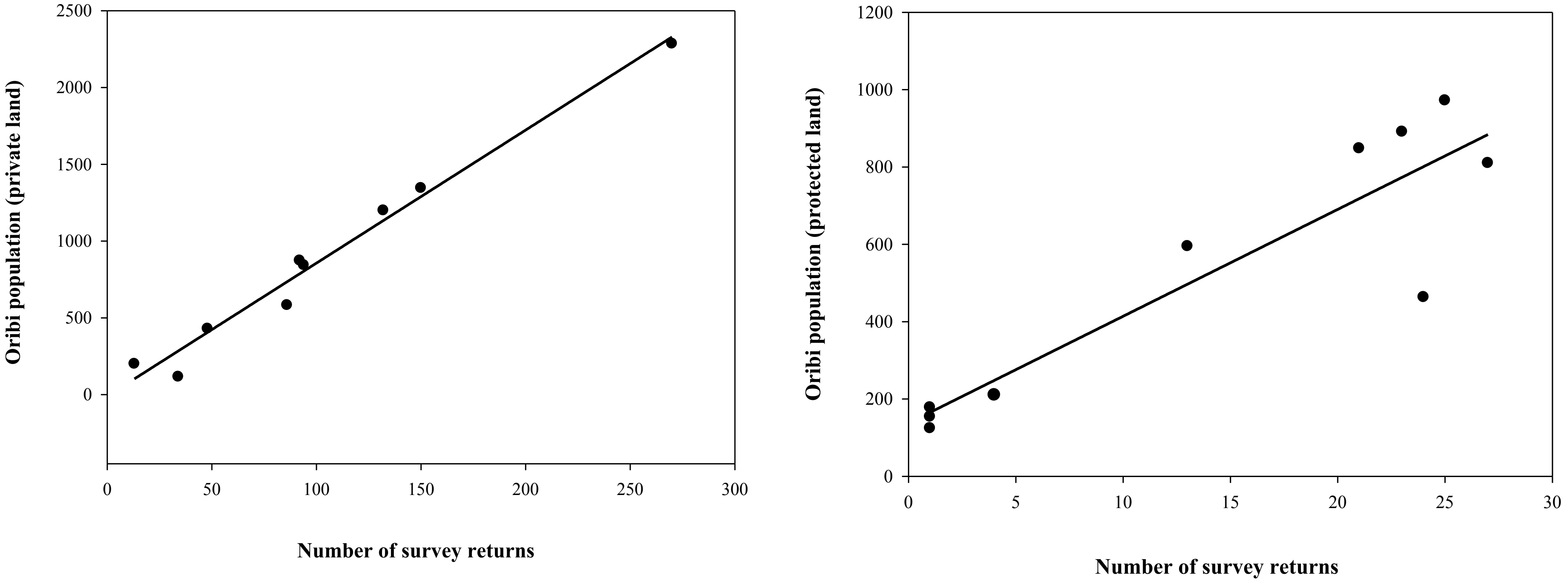

Figure 2.2 a - b: Relationship between oribi population numbers and the number of survey returns received from 2001 to 2014 for (a) private sites (N = 74 sites) ($r^2 = 0.978$) and (b) protected sites (N = 26 sites) ($r^2 = 0.824$) in KwaZulu-Natal. Data obtained from the Oribi Working Group.

Over the 13-year period (2001 – 2014), oribi populations (N = 100 populations) declined on 46% of the sites, with 36% of these being private and 10% protected lands. In contrast, oribi numbers increased on 38% of sites (27% private, 11% protected lands), and remained stable on 16% of sites (11% private, 5% protected lands) (Figure 2.3). Geographically, population trends showed no pattern at a large spatial scale. However, some patterns were evident at a local scale (Figure 2.4). There were a few locations across the province where the oribi populations in close proximity showed similar trends. For example, populations were generally declining around Vryheid, but increasing in the Mount Currie region (Figure 2.4). While other sites, such as the Underberg region, showed all three patterns (Figure 2.4). The oribi populations within the protected areas were declining (Figure 2.4).

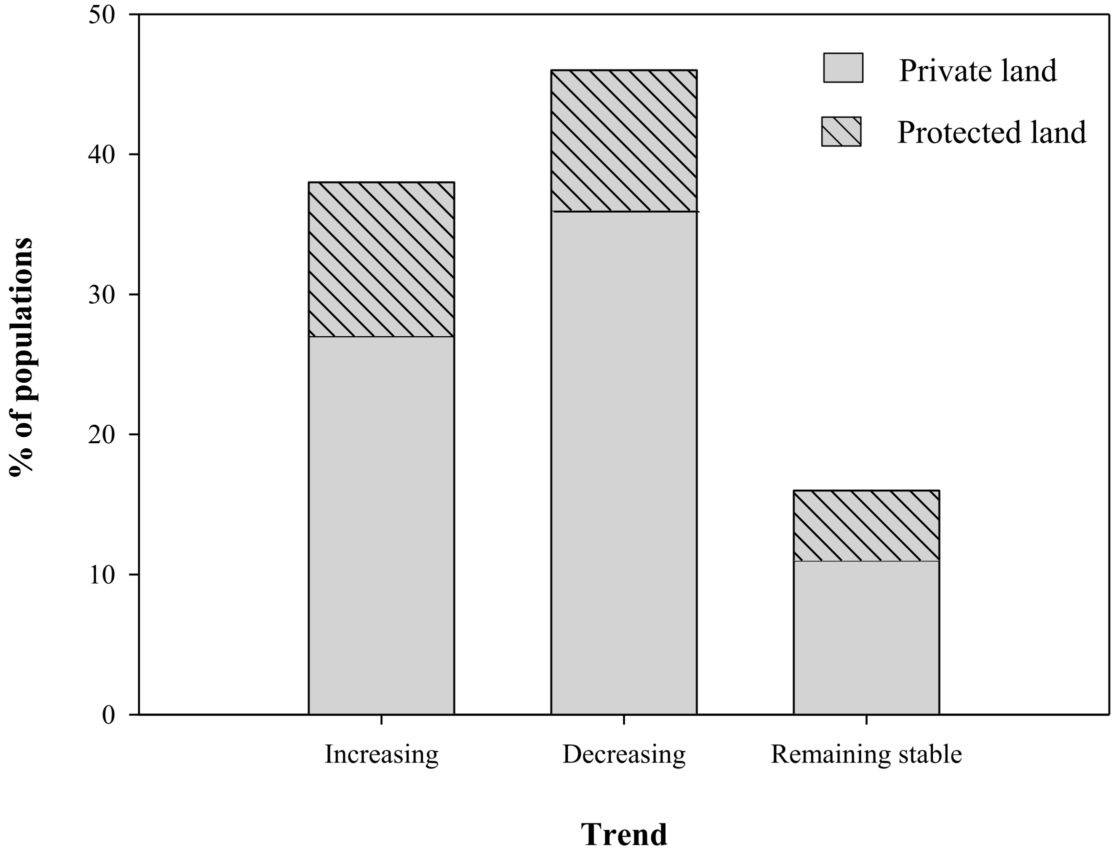

Figure 2.3: Percentage of oribi populations showing different trends in private (N = 74 populations) and protected land (N = 26 populations) in KwaZulu-Natal. Trends were determined by changes in the population growth rate (λ). Data obtained from the Oribi Working Group.

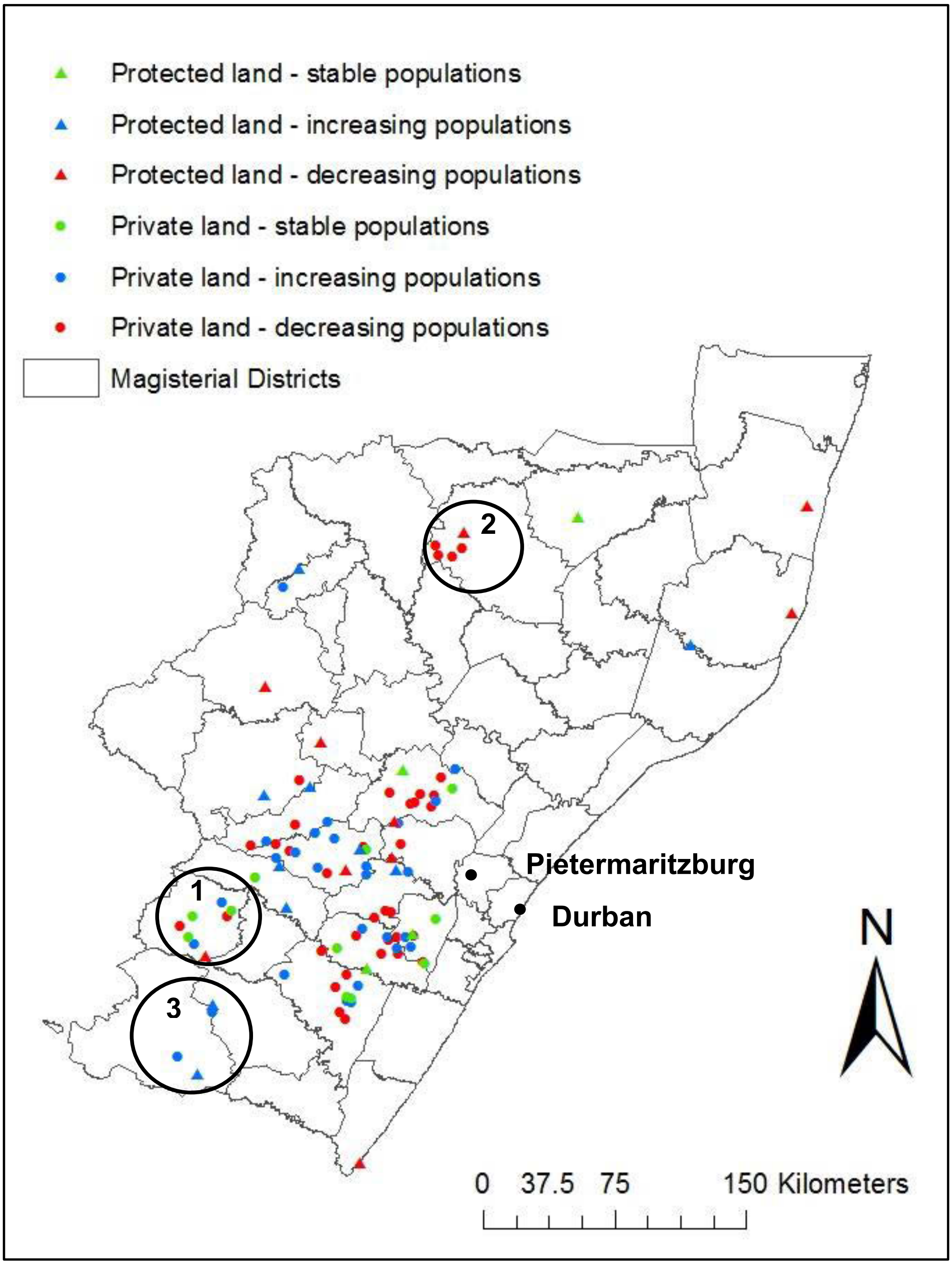

Figure 2.4: The distribution of trends for both private and protected areas for selected oribi population sites in KwaZulu-Natal. Map shows KZN Magisterial Districts. Circle labelled 1 refers to the Underberg region, circle 2 refers to the Vryheid region, and circle 3, the Mount Currie region. Data obtained from the Oribi Working Group. Sites used submitted 3 or more survey returns. (N = 100 sites). Map shows KZN Magisterial Districts.

Factors influencing oribi population growth

Of the 25 sites assessed, 14 of the oribi populations were decreasing ($0 < \lambda < 1$) (private land: N = 10; protected land: N = 4), 8 were increasing ($\lambda > 1$) (private land: N = 6; protected land: N = 2), and 3 were stable ($\lambda = 1$) (private land: N = 1; protected land: N = 2). However, the growth rates of the oribi populations on these different land types (private and protected conservation areas) did not differ significantly (Table 2.1). In contrast, initial oribi population size, the availability of suitable habitat and their interaction significantly influenced oribi population growth (Table 2.1). Based on the trend line fitted to the data, small populations (<14 individuals) tended to have increasing growth rates (λ>1), whereas populations larger than 14 individuals tended to experience negative growth rates (i.e. λ<1) (Figure 2.5). However, the variance around small population sizes was high, showing that small populations could either have increasing or decreasing growth rates (Figure 2.5). With regards to the effect of suitable habitat available on population growth, the pattern was significant (Table 2.1), but this is not a robust trend based on high observed variance (Figure 2.6). Fitting a trend line to the data illustrated that when the availability of suitable habitat was greater than 600 ha, oribi populations tend to experience increasing population growth rates (λ>1) (Figure 2.6). In contrast, those populations that have access to <600 ha tend to have decreasing growth rates. This was determined from the interception of the two lines (trend line and $\lambda = 1$) (Figure 2.6).

Moreover, there was a significant interaction between initial oribi population and suitable habitat available and their influence on lambda (Figure 2.7). Specifically, when the initial population size of oribi was large and the availability of suitable habitat was low, oribi experience decreasing population growth rates (λ<1, shown as blue in Figure 2.7). However, as the initial population size of oribi decreased, and the availability of suitable habitat increased, oribi population growth rates gradually increased (Figure 2.7). Ultimately, the highest oribi population growth rates were achieved when the initial population size was less than 14 individuals and there was more than 600 ha of suitable habitat available (Figure 2.7). However, growth rate then declined (i.e. $\lambda<1$) as the availability of suitable habitat increased to approximately 1000 ha (Figure 2.7).

Table 2.1: Generalized Linear Models showing factors that influence oribi population trends (λ) across KwaZulu-Natal. Significant factors and interactions highlighted in bold.

Model	Factor	Wald χ^2	df	p
1	Land Type	0.937	1	0.333
2	Initial oribi population size	151.010	1	**<0.001**
	Amount of suitable habitat available	11.529	1	**0.001**
	Initial population size x suitable habitat available	133.032	1	**<0.001**
3	Grazing regime	0.084	1	0.772
	Initial oribi population size	30.543	1	**0.022**
	Grazing regime x initial oribi population size	28.032	1	**0.031**
4	Grazing regime	0.014	1	0.906
	Amount of suitable habitat available	37.134	1	**0.045**
	Grazing regime x suitable habitat available	217.768	1	**<0.001**
5	Dog hunting	0.0020	1	0.967

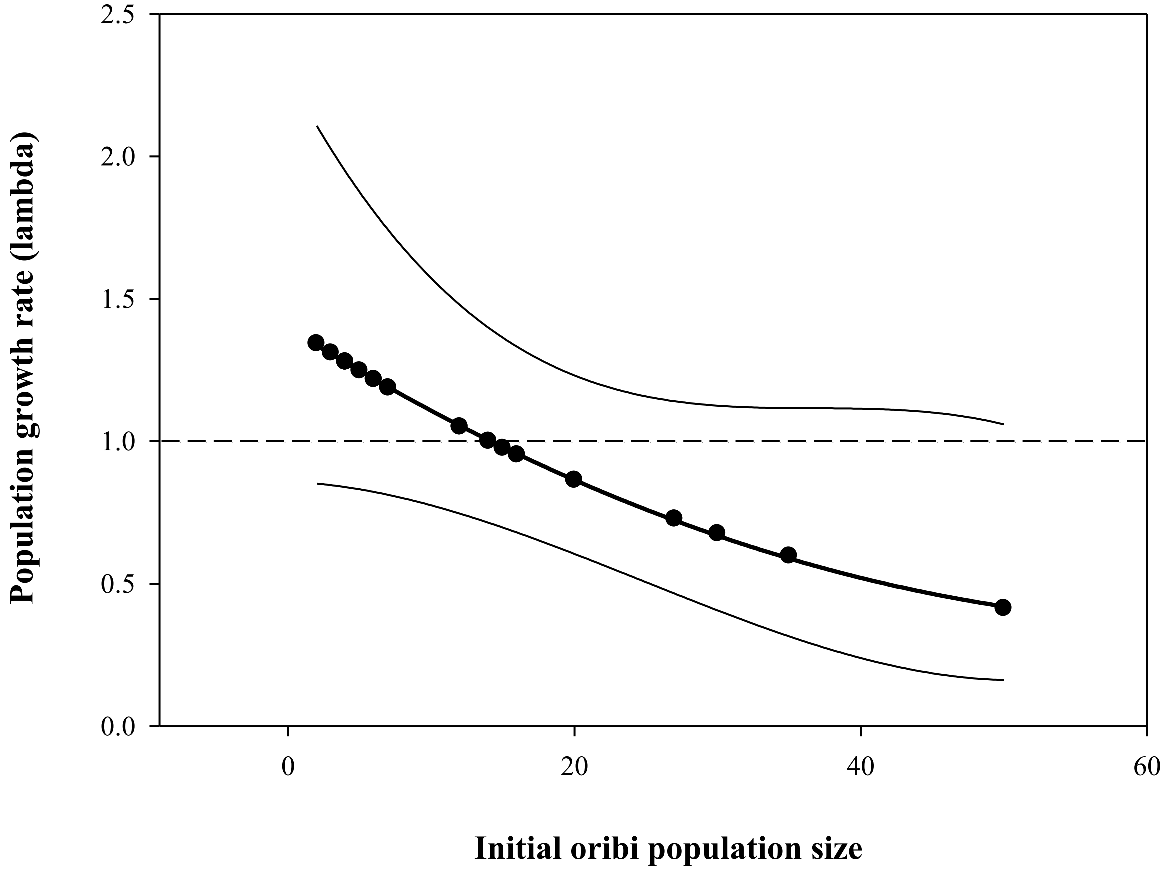

Figure 2.5: The influence of initial oribi population size on population trends (λ) for private and protected sites (N = 25 sites) in KwaZulu-Natal. The bold solid line represents the trend line with 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

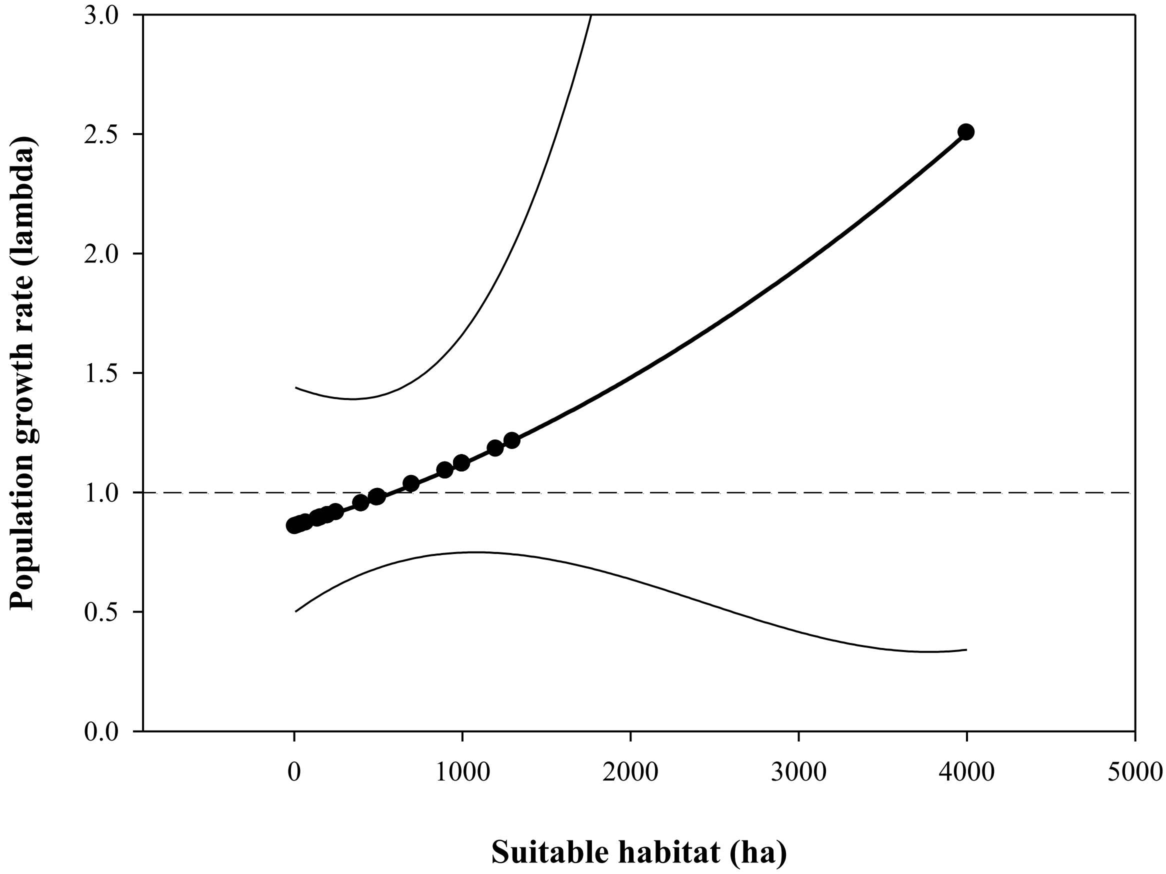

Figure 2.6: The influence of suitable habitat available on population trends (λ) for private and protected sites (N = 25 sites) in KwaZulu-Natal. The bold solid line represents the trend line with 95% confidence intervals (thin solid lines). When $\lambda = 1$, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

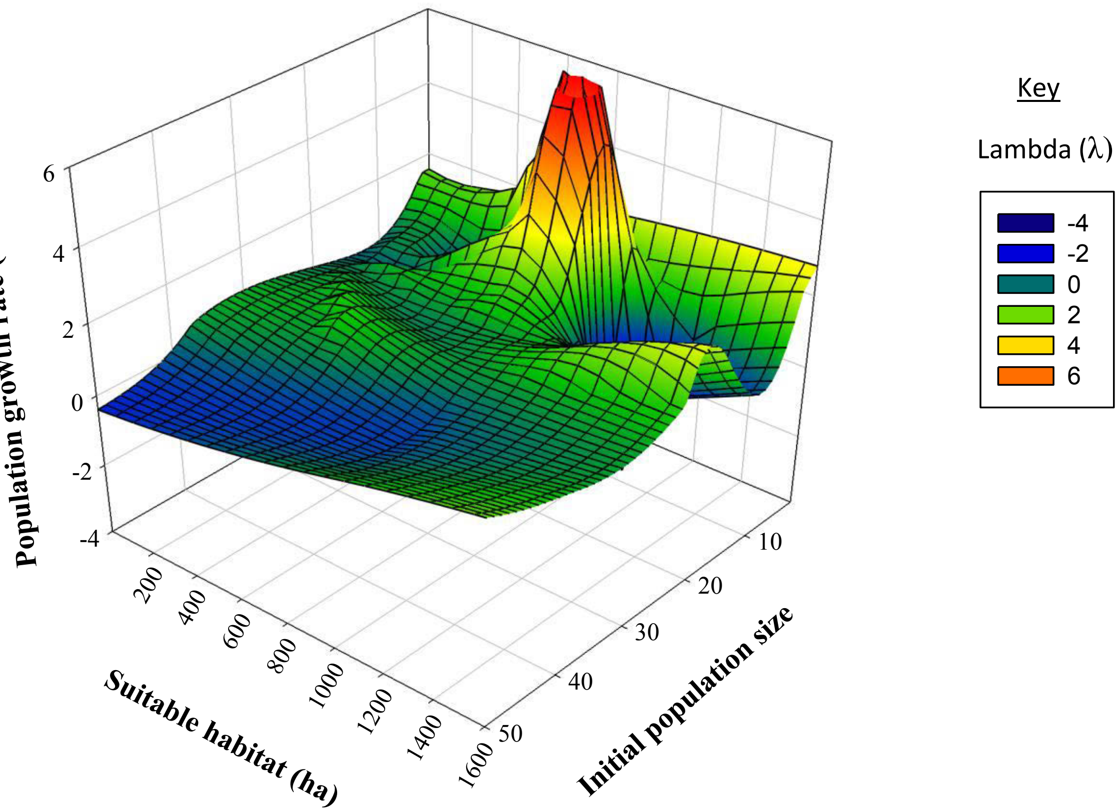

Figure 2.7: 3D mesh diagram representing the interaction between initial oribi population size and suitable habitat and their influence on lambda (λ). When λ = 1, population growth is stable.

Livestock grazing regime did not significantly influence oribi population growth rates (Table 2.1). However, 'grazing regime x initial oribi population size' significantly influenced growth rates (Table 2.1). Specifically, as initial oribi population sizes increased from 3 to 50, the growth of these populations living on either rotational or continuous grazing systems declined (Figure 2.8). Based on the trend lines, under rotational grazing systems, population growth rates increased when the population was <10 individuals, while larger populations (>10 individuals) had decreasing growth rates. Furthermore, under continuous grazing, populations with <18 individuals had increasing growth rates. Larger populations (>18 individuals) had decreasing growth rates (Figure 2.8). Overall, populations living on continuous grazing systems had higher growth rates compared to populations on rotational grazing systems. However, the variance observed around these trend lines was high.

Moreover, 'grazing regime x amount of suitable habitat available' significantly influenced growth rates (Table 2.1). Oribi population growth rates increased for both grazing regimes as the amount of suitable habitat for oribi increased (Figure 2.9). Based on the trend lines, continuous grazing had higher population growth rates compared to rotational grazing. Under rotational grazing systems, in areas with <1400 ha of suitable habitat population growth rates decreased. However, in areas with >1400 ha of suitable habitat, growth rates increased. A similar trend was observed for growth rates under continuous grazing, but the cut-off point was 400 ha of suitable habitat (Figure 2.9). Thus, the significant differences in oribi growth rates likely lie between areas of different grazing regimes where the amount of suitable habitat lies between 400 and 1400 ha. However, again, the variance observed around these trend lines was high. Lastly, dog hunting did not significantly influence oribi population growth rates (Table 2.1).

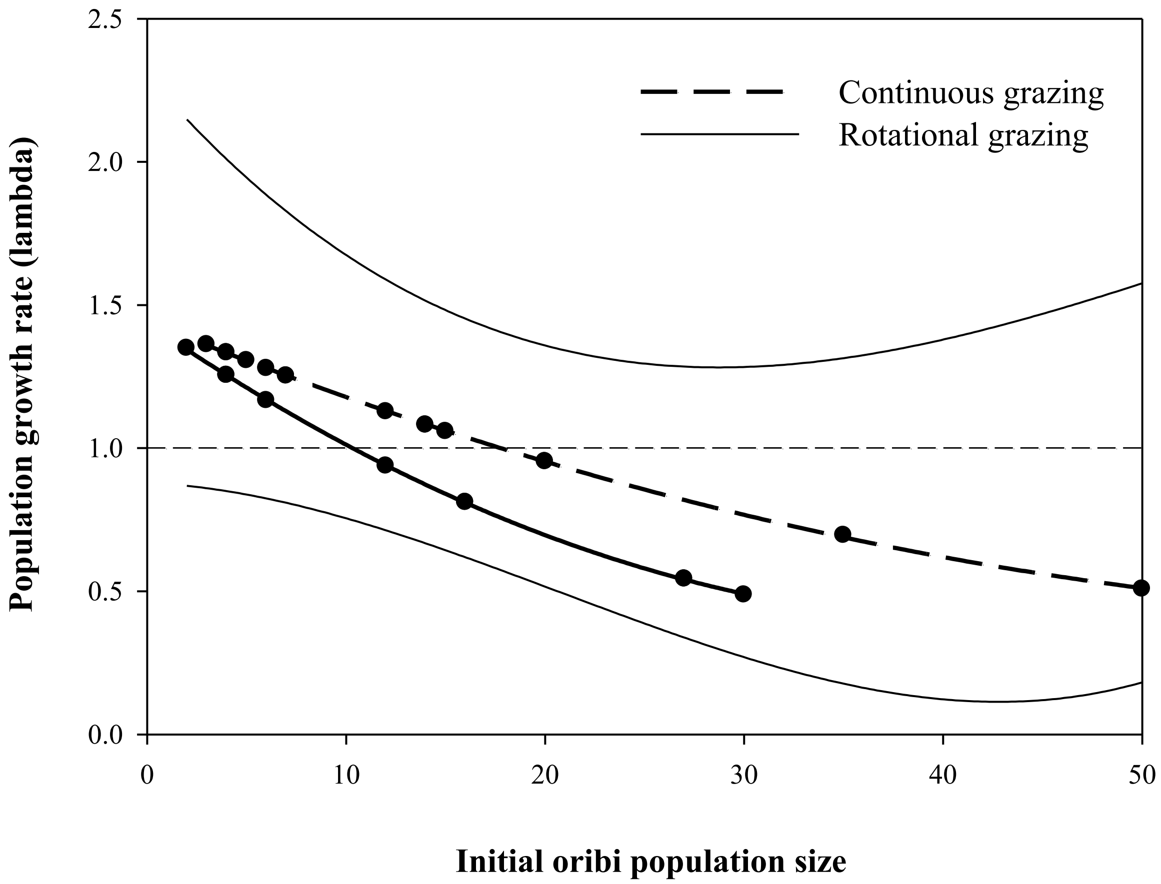

Figure 2.8: The interaction between initial oribi population size and grazing regime and their influence on lambda (λ) for oribi populations living on rotational (solid line: N = 10 sites) and continuous (dotted line: N = 15 sites) grazing systems (N = 25) in KwaZulu-Natal. Trend lines have 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

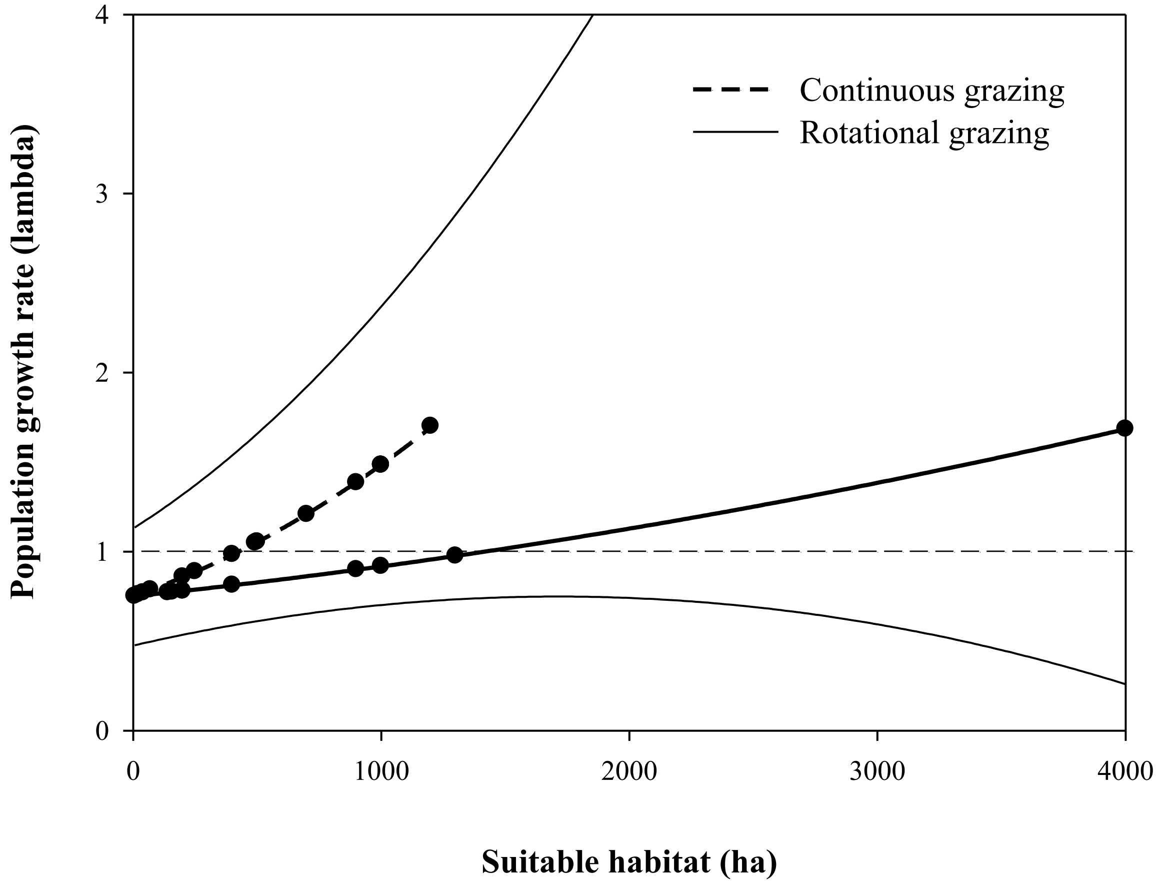

Figure 2.9: The interaction between availability of suitable habitat and grazing regime and their influence on lambda (λ) for oribi populations living on rotational (solid line: N = 10 sites) and continuous (dotted line: N = 15 sites) grazing systems (N = 25) in KwaZulu-Natal. Trend lines have 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

Discussion

For threatened species, an understanding of the factors that drive population dynamics is essential for conservation efforts (Gordon et al. 2004, Sinclair et al. 2006). In South Africa, oribi antelope are currently listed as vulnerable, yet little is known about their population dynamics (Shrader et al. In press). The results of this study suggest that oribi numbers have increased between the years 2012 and 2014. However, this apparent increase was due to improvement in survey effort and improved counting methods, and not an actual increase in oribi numbers (Little and Magwaza 2013). I found that the key factors driving the population dynamics of oribi were initial population size and the availability of suitable habitat. The trend line suggested that small initial oribi populations (2-14 individuals) had higher growth rates than larger ones. However, the variance around this trend line was high. Moreover, these growth rates increased when the amount of suitable habitat was more than 600 ha. I found that grazing regime significantly interacted with initial population size and the availability of suitable habitat. Based on the trend lines fitted to the data, growth rates decreased on both grazing systems as population size increased. Moreover, growth rates increased on both grazing systems as the availability of suitable habitat increased. Populations on continuously grazed sites had higher growth rates than those on sites with rotational grazing by cattle. Again, however, the variance around these trend lines was high, indicating that there may be some other factor driving these trends.

Small populations are generally more susceptible to change than larger populations (Bennett and Saunders 2010). This can be due to a range of stochastic effects, including demographic stochasticity (variation in birth and death rates, gender ratio's), environmental stochasticity, or genetic problems (inbreeding depression) (Lynch et al. 1995). However, if food availability is high, and a population is well below ecological carrying capacity, then the population should grow (Bowyer et al. 2014). For the oribi populations in KwaZulu-Natal, small populations had both increasing and decreasing growth rates. The increasing growth rates suggest that the small population sizes were well below ecological carrying capacity and thus individuals had access to sufficient resources. However, some of the small populations may have been impacted by stochastic effects, which resulted in decreasing growth rates.

The decreasing growth rates recorded for large populations may be explained by the fact that oribi are territorial. Males tend to defend territories of approximately 60 ha (Everett 1991, Adamczak 1999, Coverdale et al. 2006). Thus, small populations still require relatively large areas (>600 ha) to survive and grow. As a result, territorial requirements likely link in with the significant interaction I found between initial population size and the availability of suitable habitat at each of the different locations. When populations were small and there was a high availability of suitable habitat, males were likely able to establish territories and there was sufficient habitat for additional territories as the population grew. However, some of the small populations (~10 individuals) that had access to >800 ha of suitable habitat had low growth rates. This again can be explained by the fact that small populations are more susceptible to stochastic effects, even though they may have access to enough suitable habitat. Ultimately, this study suggests that the optimum initial population size for oribi should be at an intermediate level (~14-30 individuals), provided that these populations have access to sufficient amount of suitable habitat (i.e. >600 ha) (Figure 2.7). At this level, oribi likely are less at risk from perturbations like smaller populations. Moreover, they still have enough space to establish territories compared to larger populations.

However, space is not the only habitat feature that oribi require. Oribi also require grassland habitats that have a high heterogeneity with regard to grass height in order for them to survive and reproduce (Everett et al. 1991, Stears 2015). Oribi need tall grass for feeding, cover from predators and concealment of young, while short grass areas are also needed for feeding (Smithers 1983, Everett et al. 1991, Stears 2015). This type of habitat can be achieved through correct habitat management. For example, Everett et al. (1991) suggested using a combination of mosaic burning and mowing/grazing to provide oribi with access to both tall and short grass. Oribi have small body sizes (~14 kg) (Reilly 1989), therefore, they need to feed selectively in order to obtain adequate nutritional gain (Sinclair et al. 2006, Stears 2015). Preferred foraging sites include areas that have recently been mowed or burnt, because they tend to have regrowth with higher protein and energy content, and lower fibre content compared to unmanipulated areas (Everett et al. 1991). If the availability of tall grass for cover is low, oribi are exposed to greater predation risk. Therefore, the management of grasslands to ensure heterogeneity is important for the survival of oribi.

Another way in which heterogeneity in grass height could be achieved is through grazing (Adler et al. 2001). Ultimately, through their foraging, cattle can alter grass height and heterogeneity (Stears 2015). The type of grazing regime practised can affect grass heterogeneity and ultimately affect population sizes and availability of suitable habitat. My study shows that as oribi population size increased, overall growth rates of the oribi populations decreased on both rotational and continuous grazing systems. However, the trends suggest that continuous grazing systems might be slightly better at facilitating oribi population growth. This is reflected in the fact that population growth on continuous grazing systems declined at larger oribi population size (i.e. >18 individuals) compared to those living on rotational grazing systems (>10 individuals). However, due to the high variance around these estimates, the differences caused by the two grazing systems are unlikely to be great. Thus, my data indicates that larger oribi populations grow more slowly irrespective of grazing regime, and this is likely to a combination of reduced grass heterogeneity due to increased grazing pressure from livestock or wildlife (Stears 2015), and the territorial nature of oribi limiting space for population growth (Everett 1991).

In addition, populations living on rotational grazing systems had lower growth rates than populations living on continuous grazing systems. This is because in rotational grazing, the availability of tall grass may be reduced across the property, resulting in less suitable habitat being available (O'Reagain and Turner 1992). However, this is dependent on how frequently the animals are moved back onto a previously grazed camp. If oribi do not have access to tall grass, they are at risk from predation. Continuous grazing likely provides greater heterogeneity in grass height for oribi. However, this will vary depending on stocking rates. This can ultimately explain lower growth rates in populations under rotational grazing systems. However, there was a high variance around this trend. Some small populations under rotational grazing had increasing growth rates. Teague and Dowhower (2003) showed that rotational grazing reduces degradation and allows a patch to recover from overgrazing. Rotational grazing can therefore be used as a management tool for farmers to ensure the sustainable use of grasslands, as long as there is a high availability of suitable grassland. One way to obtain heterogeneity within grasslands is to manage the amount of time animals stay in a single camp, and how often they are rotated between camps. In addition, it is important whether camps are used multiple times, as this will influence grass heterogeneity. Populations living on continuous grazing systems may experience these decreasing growth rates because the availability of grass regrowth may be more spatially distributed because the size of camps are generally larger than in rotational grazing. However, this will depend on stocking rates. Stears (2015) found that different stocking rates within a continuous grazing system resulted in different patterns. Specifically, at low stocking rates, grass regrowth was high, and oribi and cattle utilised the same species and grass height (Stears 2015). At high stocking rates, there was less regrowth and oribi had to adjust their feeding to tall grass not used by cattle (Stears 2015).

Furthermore, my study highlights the fact that as the availability of suitable habitat increased, the growth rates of populations on both grazing systems increased. Again, populations living on rotational grazing systems had lower growth rates than populations living on continuous grazing systems. However, the variation around this trend line was high. Some populations that had the same amount of suitable habitat available and exposed to the same grazing regime showed opposite growth rates. This suggests that there was likely some other factor that drove these different trends. One possibility could be the combination of stocking rates of cattle and the grazing regimes at each of the sites. However, stocking rate data were not available for many of my sites, thus I could not include it in my model.

One aspect that I did not look at in this study, and which is important, is the spatial scale at which suitable habitat is made available to oribi (Stears 2015). This can be linked into the management of cattle in the grazing regime. For example, in rotational grazing, if a lot of camps are grazed next to each other, the availability of tall grass is reduced in a large area. However, if adjacent camps are grazed and rested then the scale of suitable habitat is greatly increased, which benefits oribi. Another factor that could be driving this variation, and one that I did not look at in this study, is the stocking rates of other herbivores at each farm for each grazing regime. For example, rotational grazing under high stocking rates will drastically affect grass heterogeneity. Therefore, if there is not enough suitable habitat available and the population is large, competition will increase (Bowyer et al. 2014).

Another factor that might explain the interactions I found between grazing regime and initial population size, as well as the interaction between grazing regime and amount of suitable habitat available, is the trade-off associated with competition and facilitation (Odadi et al. 2011, Stears 2015). For example, Odadi et al. (2011) found that wild herbivores (i.e. plains zebra *Equus burchelli*, Grevy's zebra *E. grevyi*, African buffalo *Syncerus caffer*, eland *Tragelaphus oryx*, hartebeest *Acelaphus buselaphus*, oryx, *Oryx gazella*, Grant's gazelle

Gazella granti, African elephant *Loxodonta africana* and giraffe *Giraffa camelopardalis*) reduced food availability for cattle (i.e. competition). This competition ultimately led to the cattle achieving lower food intake, and thus reduced weight gain during this period. However, wild ungulate feedings facilitated cattle foraging during the wet season by enhancing herbage growth and forage quality, and decreasing the cover of standing dead grass stems, resulting in improved cattle condition (Odadi et al. 2011). Similarly, Stears (2015) found that wet season cattle foraging indirectly competed with oribi by reducing the availability of the oribis' preferred grass species during the dry season. In contrast, during the wet season, oribi maintained higher crude protein intake rates feeding in areas with cattle than feeding in ungrazed camps. This higher nutritional intake was likely driven by the availability of high quality regrowth which grew in response to cattle foraging (Stears 2015). Therefore, facilitation due to grazing can be positive for oribi population growth rates.

The patterns I found for the interactions between oribi population size and availability of suitable habitat, and their influence on population growth rates could also be as a consequence of a low sample size of data from large reserves (i.e. >1300 ha). The majority of the populations in this study were found in areas that had access to <1300 ha of suitable grassland habitat, with only one outlier reserve, which had access to 4000 ha of suitable habitat. Thus, without a number of large populations with which to include in the analysis, the one point has a great and likely unrealistic effect on the overall trend. A similar situation also likely affects the relationship between initial population size and population growth rate. The reason for these smaller populations is likely attributable to the small population sizes that oribi are generally found in due to the rarity of this species. However, it can also be as a result of counting/sampling inaccuracies in larger areas. Nevertheless, as there are a few initial populations between twenty and forty, the effect of the largest population (i.e. 50) on the overall pattern is likely less than it is for the relationship between suitable habitat and population growth. Lastly, the assessment of the amount of suitable habitat available within a particular site was based on estimations of the perceptions of landowners, therefore, the accuracy of the data may be questionable. Site visits could, however, verify these data.

Although poaching via dog hunting was found to be non-significant, it is a major threat to oribi populations in KwaZulu-Natal (Viljoen 1982, Everett 1991, Marchant 1991, Coverdale et al. 2006, Shrader et al. In press). Moreover, it was absent in only one of the sites. However, because it is illegal, it is difficult to get an accurate measurement of the impact of poaching on oribi populations. For example, a poaching incident on a property gives no indication of how many oribi were killed, if any at all. To accurately assess the impact of poaching, it is necessary to determine the frequency at which it occurs as well as quantify the number of oribi that are killed. However, this can occur sometimes without the landowner knowing, and thus, this information is extremely difficult to quantify. As a result, although I did not find that poaching affected oribi population growth, the poor quality of the data makes this result unreliable. Thus, poaching should not be discarded as a factor influencing oribi population dynamics. Moreover, with the continued rise in the level of illegal poaching (Magwaza and Little 2014), any study that could quantify the direct impact of poaching on oribi populations would be extremely helpful to oribi conservation efforts.

In conclusion, the overall current oribi population in KwaZulu-Natal is estimated as at least 1583 individuals. The results of this study provide greater insight into this estimate in that I found that a high number of widely distributed populations within KwaZulu-Natal were decreasing. A hopeful sign is that despite potential challenges associated with small populations, there are some populations within KwaZulu-Natal that have increasing growth rates. Additionally, I was able to show that a greater amount of suitable habitat increases oribi population growth. Finally, oribi populations on continuously grazed sites have higher growth rates than those on rotational grazing systems. Even though the variation within each of the variables in this study was high (populations under similar conditions showed different trends), a combination of these findings suggests that if landowners want to maintain oribi on their property, they should have an area of more than 600 ha of suitable grassland habitat available in order to achieve higher population growth rates. In addition, initial oribi populations with an intermediate number of individuals (~14-30 individuals) are most likely to grow in numbers. This is likely because they have a lower risk of extinction compared to smaller populations, while still having enough suitable habitat for the population to grow and males to be able to establish territories.

A key finding of my study is that a majority of oribi populations in KwaZulu-Natal are decreasing. As a result, there is a strong need for conservation efforts to be put into place. My results provide insight into some of the important factors that drive oribi population dynamics. Moreover, these findings can be used in management and conservation decisions in order to increase oribi population growth rates and guide introductions.

Lastly, sample effort plays a key role in determining the quality of data (Munn and Drever 1990). In line with this, I found that oribi population estimates are reliant on survey returns, emphasizing the need to urge all private landowners who have oribi on their property to conduct counts and submit their oribi numbers. Consistent returns provide more reliable data with which to generate population estimates (Thomas et al. 2010). Moreover, by conducting the counts during the start of the spring when the oribi move onto the burns, and are thus easier to count, the accuracy of the return data is greatly improved. This, in turn provides key information for improved long-term conservation initiatives and management practices for oribi in South Africa.

Chapter 3
An assessment of oribi relocations in KwaZulu-Natal. Can this be used as a conservation tool in South Africa?

Conservation efforts, including relocations, have been carried out for many mammalian species. However, the assessment of the variability in success rates of relocation attempts suggests that prior to relocating animals, it is important to follow a basic set of criteria to increase the probability of a relocation of being a success. This includes aspects such as identifying and removing threats, setting clear conservation goals, and having good management and monitoring plans. The oribi antelope (*Ourebia ourebi*) is listed as vulnerable in South Africa. This is in part because they are generally found in small, fragmented populations that live in areas that are under threat from land transformation. As a result, relocations have been used as a conservation tool for oribi over the past 16 years in KwaZulu-Natal. However, the success of these relocations has been poorly documented. The aim of this study was to determine 1) the success rate of previous oribi relocations in KwaZulu-Natal, South Africa, thus indicating whether relocations have been a successful conservation tool for oribi, and 2) the factors driving the success/failure of these relocations. Results indicate that to date, oribi relocations (N = 10) only had a success rate of 10% (N = 1). This is likely due to the majority of relocation sites not meeting all the basic criteria required for a successful relocation, such as the removal of threats or long-term post-release monitoring. For example, the removal of threatening factors (e.g. predators) in the release area was only considered in 50% of relocations. In addition, long-term monitoring was lacking at many of the sites. Not surprising, the only successful oribi relocation considered all the basic criteria prior to the relocation. To determine the factors that resulted in the success or failure of the oribi relocations, I focused on the population growth rate (i.e. λ) of the relocated populations. I found that the majority of sites had small populations (<18 individuals) and availability of suitable habitat of less than 800 ha, which resulted in decreasing oribi population growth rates. In addition, both high and low stocking rates of other large herbivores resulted in the growth rates of oribi populations decreasing. However, the growth rates of the oribi populations in high stocking sites (<3.5 ha/AU) had higher growth rates than those sites with low stocking rates (>3.5 ha/AU). Moreover, I found a significant interaction between suitable habitat available and stocking rates and their influence on oribi population growth rates. Ultimately, the highest growth rates were achieved when there was more than 800 ha of suitable habitat available and stocking rates were less than 3.5 ha/AU. Stocking rates alter grassland heterogeneity, which is vital for the survival of oribi. Results of this study suggest that if landowners want to ensure that introductions of oribi on their property are successful, then the basic criteria for successful relocations need to be followed.

Keywords: *conservation, long-term monitoring, management, relocation, success rate*

Introduction

A range of conservation efforts, including relocations, have been carried out for a number of endangered and threatened species (Muths et al. 2014). Relocations involve the movement of an animal or population of animals from an area where they are currently threatened (e.g. by agricultural development) to a more suitable area where they will be less susceptible to habitat loss, and preferably where they historically occurred (Dodd and Seigel 1991). Relocation is a popular and commonly used tool for the conservation of threatened species (Fischer and Lindenmayer 2000). Yet, what is a successful relocation?

Because the goal of any conservation programme is to create a viable, self-sustaining population (Kleiman 1989, Dodd and Seigel 1991, Jule et al. 2008), a successful relocation should be able to provide evidence of this (Griffith et al. 1989). For example, it is not enough to observe breeding individuals within a population as evidence of a success. New-borns should be observed and the population should be identified as increasing to confirm that a self-sustaining population has been met (Griffith et al. 1989, Dodd and Seigel 1991). Because this can take a long time, long-term monitoring of these relocated populations is extremely important (Sarrazin and Barbault 1996). Only after a long-term assessment can a relocation be classified as being successful or not. 'Long-term assessment' will depend on the life-history characteristics of the species being relocated (Sarrazin and Barbault 1996). This will help to identify whether the released animals survived, and whether they successfully reproduced or not.

There have been both successes and failures when it comes to relocating animals (Armstrong and Seddon 2007). Griffith et al. (1989) found an overall success rate of 44% when reviewing translocation programmes for birds and mammals. Success rate was influenced by ecological factors such as habitat suitability where the individuals were released, whether the released individuals were wild or captive bred, and the feeding habits of adults (Griffith et al. 1989). Some large mammalian herbivore populations are critically low and are therefore priority species for conservation efforts. Many large mammalian herbivores have high economic value because of sport hunting (Gordon et al. 2004). In addition, they drive the structure, composition, and functioning of ecosystems (Gordon et al. 2004). Therefore, the conservation of these species is of great importance.

There have been many successful relocations that have helped to conserve a range of species (e.g. Penzhorn, 1971; Pienaar 1994; Reading et al. 1997; Seddon et al. 2012). For example, the Arabian oryx (*Oryx leucoryx*) was successfully re-i(Seddon et al. 2012)ntroduced (i.e. the population gre(Pienaar 1994)w continuously over 14 years) in Oman (Spalton et al. 1999). Within eight years and after two reintroductions, the population was sitting at 100 individuals in 1990. The population continued to grow to 280 individuals after five years and further grew to over 400 individuals by 1996 (Spalton et al. 1999). In South Africa, the white rhinoceros (*Ceratotherium simum*) was successfully re-introduced into the Kruger National Park through multiple relocations during the 1960's (Pienaar 1970). In total, 141 individuals were moved with only six deaths. Calves were observed in subsequent years, with the population between 155 and 160 individuals and rising in 1970 (Pienaar 1970). At present, Kruger has the largest population of white rhinoceros in the world (Ferreira et al. 2012). Elsewhere in South Africa, the relocation of springbok (*Antidorcas marsupialis*) and blesbok (*Damaliscus dorcas phillipsi*) to Mountain Zebra National Park was also extremely successful (Penzhorn 1971). Springbok numbers increased to such an extent that they were used as a source population for other national parks (Penzhorn 1971). These examples and others, indicate that relocations can be used as a successful conservation tool for a wide range of mammalian herbivores.

However, relocation of mammalian herbivores have not always be successful (Pienaar and Van Niekerk 1963, Griffith et al. 1989, Jones and Witham 1990, Guy et al. 2015).

Marchant (1996) assessed the survival of six antelope species that were bought at wildlife auctions. These included blue duiker (*Philantomba monticola*), red duiker (*Cephalophus natalensis*), oribi (*Ourebia ourebi*), suni (*Neotragus moschatus*), common reedbuck (*Redunca arundinum*) and mountain reedbuck (*Redunca fulvorufula*). The success rate (defined by the survival of species) of all the relocations was poor. This was attributed to transport stress or unsuitable habitat (Marchant 1996). The availability of suitable habitat can be influenced by management practices, such as existing stocking rates, which can influence habitat heterogeneity. Marchant (1996) also found that many of the animals were introduced to areas outside of their natural distribution range. Moreover, these animals were not monitored post-release, which resulted in little information about what had happened to them (Marchant 1996).

Another factor that can influence relocation success is the animal itself. Relocating captive animals can be risky. Apart from being highly susceptible to predators, captive animals tend to show a loss of natural behaviours associated with wild fitness (foraging, hunting, predator avoidance), and they display lowered immunity to diseases (Jule et al. 2008). Studies have shown that using wild-caught animals tends to result in higher relocation success rates than using captive-born animals (Griffith et al. 1989, Fischer and Lindenmayer 2000, Mathews et al. 2005, Jule et al. 2008). Griffith *et al*. (1989) found a 75% success rate of translocations that involved wild animals, and only a 38% success rate for captive reared individuals. In another study conducted on oribi, 29 wild animals were relocated to the Kruger National Park in an attempt to reintroduce this species (Pienaar and Van Niekerk 1963). However, within 3 months of release, more than 50% of the animals had died. Various factors were responsible for this, however, predators (leopard and jackal) as well as an undesirable time of capture (i.e. during late winter and spring as most of the females captured during this time were pregnant) for the relocation were suggested (Pienaar and Van Niekerk 1963).

Linklater and Swaisgood (2008) found that the best release sites for the survival of the black rhinoceros (*Diceros bicornis*) should be on large reserves with a low release density (i.e. number of individuals in the park after release) to reduce encounter rates with conspecifics or other hazards, such as fenced boundaries. In small reserves with high release densities, more injuries and deaths occurred (Linklater and Swaisgood 2008). Frair et al. (2007) suggested that in order to increase success of relocations of elk (*Cervus elaphus*), a predator-free release site with high habitat quality should be selected. In addition, selecting source populations that are not naive to the threats in the new habitat can increase the success of relocations into risky landscapes (Frair et al. 2007).

In order to further increase relocation success rate, basic initial criteria need to be addressed for any species. Prior to any conservation efforts being conducted, the International Union for Conservation of Nature (IUCN) guidelines should be followed (Guy et al. 2015). These include: deciding when a relocation is an acceptable option, planning a relocation (clear goals, objectives, and actions), feasibility and design, risk assessment, release and implementation, and monitoring and management (IUCN/SSC 2013). For relocation purposes, there needs to be an initial assessment of the new habitat and threats that exist there before moving animals.

Pérez et al. (2012) proposed a hierarchical decision-making system in order to improve the chances of successful relocations. This comprised ten basic criteria to be assessed before any relocation is carried out. The first criterion was to determine whether the species or population is under any threat in their current habitat. The second criterion assesses whether the threatening factors are absent, or whether they have been removed or controlled in the release area. It is important to identify all possible threats faced by the target species and population prior to a relocation (Brambell 1977). If threats have not been controlled in the release area, the relocation should not be approved.

The third criterion asks whether relocation is the best conservation tool, and whether there are any alternatives. The reason for population decline should be assessed and the most suitable management options used to eliminate threats (Griffith et al. 1989, Kleiman 1989). If the decline in population is caused by human impacts, a better alternative could be the use of in-situ conservation actions (Caughley 1994), such as altering management practices like stocking rates. Criteria four examines whether the risks for the target species are acceptable. Moving animals around can promote the spread of diseases and genetic mixing (Griffith et al. 1989, Cunningham 1996). If this could possibly threaten the source or recipient populations, then the relocation is unadvisable. Similarly, criteria five looks at whether the risks for other species or the ecosystem are acceptable. Relocations can impact other species, as well as the source or recipient ecosystems (Cunningham 1996). Relocated species may become invasive (Ricciardi and Simberloff 2009).

Criteria six asks whether the possible effects of the relocation are acceptable to the local people. If relocations have the possibility of negatively affecting human lives or livelihoods, then it is unadvisable to go through with it. Local acceptance is important in ensuring whether a project will succeed, as human actions, such as poaching, could ultimately affect the survival of the released individuals (Jones and Witham 1990, Frair et al. 2007). Possibly one of the most important criteria is criteria seven, which determines whether the project maximizes the likelihood of establishing a viable population. A small population is more susceptible to change than larger ones (Stratton 2010). Small release groups can fail to establish populations due to demographic stochasticity or low reproduction and survival rates (Armstrong and Seddon 2007).

Ultimately, knowing the goal of the relocation is important. This is because key factors can be determined to ensure that a viable population is established. These factors include: the age and sex classes most appropriate, and the size and composition of groups to be relocated, release site selection, distance between release sites, timing of the releases (season of the year), and the schedule of the relocation of groups (released simultaneously or at intervals) (Kleiman 1989). The main aim of any relocation is to select a combination of individuals that will best survive with the least preparation and cost. Moreover, it needs to be determined whether the techniques used for the relocation were successful and cost-effective. This goes a long way to determining overall success of the relocation and can help future projects with following the factors that influenced success. Added to this, is that the amount of suitable habitat within the release area needs to be assessed to ensure that animals can easily adapt to their new surroundings (Kleiman 1989, Jule et al. 2008). In addition, it is important to make sure that the population in the release area is below carrying capacity to allow for the growth of the population (Brambell 1977).

Criteria eight looks at whether the project includes clear goals and monitoring plans. Long-term monitoring helps to assess progress of the species towards meeting project goals (Sarrazin and Barbault 1996). Another important consideration is whether enough economic and human resources exist, which is addressed by criteria nine. There should be sufficient economic resources from the beginning to see the project through to meet long-term goals (Kleiman 1989). Post-release monitoring – whether it is directly after the relocation, or long-term – is vital in evaluating whether a project meets its goals (Scott and Carpenter 1987). This is only possible if there are enough resources available. Lastly, criteria 10 addresses whether scientific, governmental, and stakeholder groups support the relocation. Gaining support from different organisations can go a long way to ensuring a successful project.

Without this support and the resources that come with it, long-term monitoring will be difficult (Kleiman 1989).

From 2004 to 2014, oribi were classified as endangered in South Africa (Friedmann and Daly 2004, Shrader et al. In press). Then, in 2015, oribi were down-listed to vulnerable, due mostly to greater effort being put into counting the species across its range (Shrader et al. In press). However, despite the down-listing, oribi still face a number of threats including habitat loss and poaching. One key conservation tool that has been used to address declining numbers of oribi in response to habitat loss, has been to relocate isolated and threatened oribi populations. Oribi relocations have been implemented for the past 16 years in KwaZulu-Natal. However, the success or failure of these has been poorly documented. Moreover, set criteria such as those set out by Pérez et al. (2012) have not been utilised. Thus, it is unclear whether relocations have been successful in conserving oribi populations. As a result, the aim of this study was twofold. First, to assess the success rate of previous oribi relocations conducted in KwaZulu-Natal to determine whether relocations are a good conservation tool for oribi in South Africa. Second, to determine the factors responsible for the success or failure of oribi relocations. Successful relocations in this study were determined by increasing populations (i.e. observed births) after the relocation and continued growth to date.

As oribi relocations have generally been poorly documented, and relocation criteria not considered prior to relocating the oribi, I hypothesised that the degree to which relocation criteria were considered prior to any relocation would affect the outcome of the relocation. Specifically, I predicted that relocation sites that did not consider the above 10 criteria (Pérez et al. 2012) would have decreasing populations and hence, have a low chance of being successful. Alternatively, I predicted that relocations that considered all these basic criteria would have higher success rates. Moreover, based on the results of Chapter 2, I hypothesised that oribi population size and availability of suitable habitat would influence population trends, and ultimately, relocation success. Specifically, small populations would have access to sufficient resources, resulting in population growth. However, they may also decline due to greater susceptibility to perturbations (Gilpin and Soulé 1986). In addition, oribi in areas with a high availability of suitable habitat would have increasing growth rates, thus indicating successful relocations. Because grazing from a range of herbivores can alter grass height and structural heterogeneity (Stears 2015), my third hypothesis was that stocking rates would directly affect habitat heterogeneity, and ultimately influence relocation success rates. I predicted that low stocking rates of other grazers (e.g. cattle, wildlife) would be better for oribi as there would be reduced impact on rangelands that would negatively affect oribi, and potentially lower levels of competition. In contrast, high stocking rates would likely result in greater vegetation structural impacts (e.g. reduced heterogeneity of grass height) and thus reduce the suitability of rangelands for oribi, and greater levels of competition. Finally, as many of these factors can work in conjunction, it is unlikely that one single factor determines oribi relocation success rates, but rather a combination of factors.

Methods

I obtained data on oribi relocations from the Oribi Working Group. Data consisted of, site that received oribi, site where oribi were taken from, year of relocation, and the number and sex of individuals moved. For the purpose of this study, I followed up on 10 oribi relocations previously carried out in KwaZulu-Natal to determine success rate. These relocations ranged from 2 to 10 years prior to this study. Even though it may take some time to assess whether relocations have been a success or not, I believed that the fact that oribi breed every year warranted the inclusion of the more recent relocations. Moreover, the implications of the more recent relocations are discussed. I conducted site visits to each of these locations and spoke to landowners about the oribi relocations that have occurred on their property. I determined which of the sites had used some or all of the 10 criteria prior to the relocation by asking the landowners. Furthermore, I determined population trends for each site by calculating the finite rate of increase of a population (population growth rate), termed lambda (λ). λ is the ratio of population size at one time to its size one time-unit earlier. I calculated λ by using the number of individuals in the most recent year / (number of initial resident individuals + the number of relocated individuals). I used lambda as it can be generated from population counts at successive times, even without knowing per capita birth and death rates (Stratton 2010). Lambda is a useful approach to assess the health of a population over a period of study (Nichols and Hines 2002). When $0 < \lambda < 1$, the population is decreasing. In contrast, when $\lambda = 1$, the population is stable, and when $\lambda > 1$, the population is increasing (Stratton 2010, Hone 2014). The trends helped me to identify which of the relocations were successful and which had failed. A successful relocation for this study was determined by an increasing population growth rate. Failed relocations had decreasing/stable growth rates. I classified stable growth rates as failed relocations if births and new-borns were not recorded or observed over successive years post-release.

After determining success or failure of the relocations, it was important to identify the factors influencing success rate. I used the questionnaire in Appendix 3 to obtain additional information about the relocations for each site. Only one relocation was successful with an increasing population trend, and nine were considered as failures as population decreased or remained stable (see Results). Therefore, I used lambda (λ) as a dependent variable, rather than success/fail, as I would have had a low sample size for successful relocations (N = 1 site each) to compare with failed ones (N = 9 sites). To determine the factors that could potentially affect oribi population trends (λ) across these 10 relocation sites, I used oribi population size (initial resident individuals + relocated individuals), the amount of suitable habitat available (i.e. grasslands), and stocking rates of other mammalian grazers (e.g. cattle and wildlife) at each of the sites as independent factors in the analysis. Population size was included as oribi are generally found in small populations (Everett 1991). Furthermore, small populations have the ability to grow because resources are less limited, unless the habitat available is equally small. The amount of suitable habitat available influences oribi foraging (Smithers 1983, Everett et al. 1991, Stears 2015). For my study, suitable habitat was defined as heterogeneous grassland comprising both short and tall grass. Availability of this grassland type for each site (i.e. proportion of the total site) was reported by landowners (see Appendix 3). Management (e.g. stocking rates) may differ in many ways and could potentially affect grass heterogeneity, which in turn, could influence both habitat suitability and predation risk for oribi (Stears 2015). I calculated stocking rates using the following equation: suitable habitat available (ha)/number of animal units to give a stocking rate of ha/AU for each site. Data for suitable habitat available and the number of animal units were provided by landowners for each site. Stocking rates of more than 3.5 ha/AU were considered as low, and stocking rates less than 3.5 ha/AU were considered as high. This was categorised based on the recommended stocking rates (i.e. 3.5 ha/AU) of the different Bioresource Groups (from the Department of Agriculture) that my sites fell under (Camp 1999, Hurt and Camp 1999).

Statistical analysis

I analysed the data using a model selection procedure based on small-sample corrected (second-order) Akaike's Information Criterion (AICc) values (Burnham and Anderson 1998). The model selection procedure allows multiple models to be compared simultaneously to determine the model that best fits the data. To determine whether oribi population size (resident + relocated individuals), the availability of suitable habitat, and/or stocking rates influenced population growth rates (i.e. λ across $N = 10$ sites), I used a Generalized Linear Model with a Gamma Distribution and a log link function. For the model selection procedure, I compared the full model to biologically relevant simpler models (see Table 3.2). The model with the lowest AICc value (ΔAICc = 0) provides the best fit for the given data. However, models with a difference of less than 2 AICc units have similar support for the data (Burnham and Anderson 1998). I calculated ΔAICc (Δ_i) using the following equation: $\Delta_i = AICc_i - \min AICc$, where $AICc_i$ is the AICc for the model $_i$ and min AICc is the value of the best model (Burnham and Anderson 1998). Akaike's weights are used in model averaging. I first determined the relative likelihood of the model, which is exp (-0.5 * ΔAICc score for that model) (Burnham and Anderson 1998). Akaike's weight was calculated with this value divided by the sum of these values across all models (Burnham and Anderson 1998). All statistical analyses were conducted using IBM SPSS Statistics 21.

Results

Of the 10 relocation events, only one was considered to be successful (i.e. showed by an increasing population trend). Not surprising, this was the only site that considered all 10 criteria prior to relocation. On average, the failed relocations considered eight out of the 10 criteria. Only two of the criteria were considered by all 10 sites prior to relocation. These were whether relocations are the best conservation tool and whether it is acceptable to the local people. Moreover, some of the criteria were not considered by most of the sites. For example, criteria two, which assesses whether threatening factors have been removed or controlled in the release habitat, was considered by only five of the 10 sites (Figure 3.1). In addition, criteria eight, which looks at whether the project has clear goals and monitoring, was considered by only six of the 10 sites (Figure 3.1). All the sites considered at least six or more of the criteria prior to any relocation (Figure 3.2). Three sites had considered nine out of the 10 criteria, however, the one criteria that they all dismissed was whether the threatening factors had been removed or controlled. Eight of the 10 sites had decreasing population growth rates, resulting in a failure of the relocation. A stable trend was recorded for one of the sites. However, because the population was stable for five years, and no births were recorded or observed, I classified it as a failed relocation.

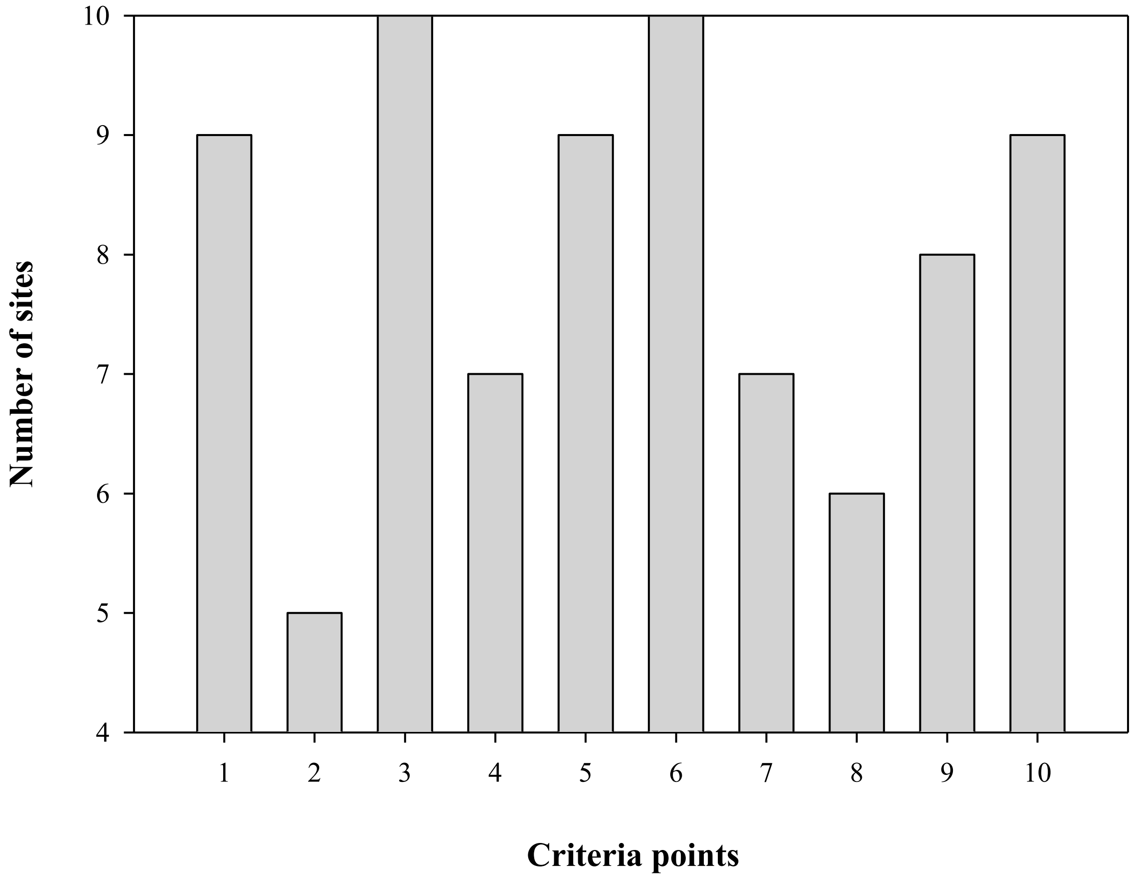

Figure 3.1: The number of sites which considered each criteria prior to the relocation (N = 10 sites). Criteria are: 1) Is the species under threat? 2) Have threats been removed/controlled? 3) Is a relocation the best conservation tool? 4) Are risks for the target species acceptable? 5) Are risks for other species or the ecosystem acceptable? 6) Is the relocation acceptable to local people? 7) Is the project likely to establish a viable population? 8) Does the project include clear goals and monitoring? 9) Do enough economic and human resources exist? 10) Do scientific, governmental and stakeholder groups support the relocation?

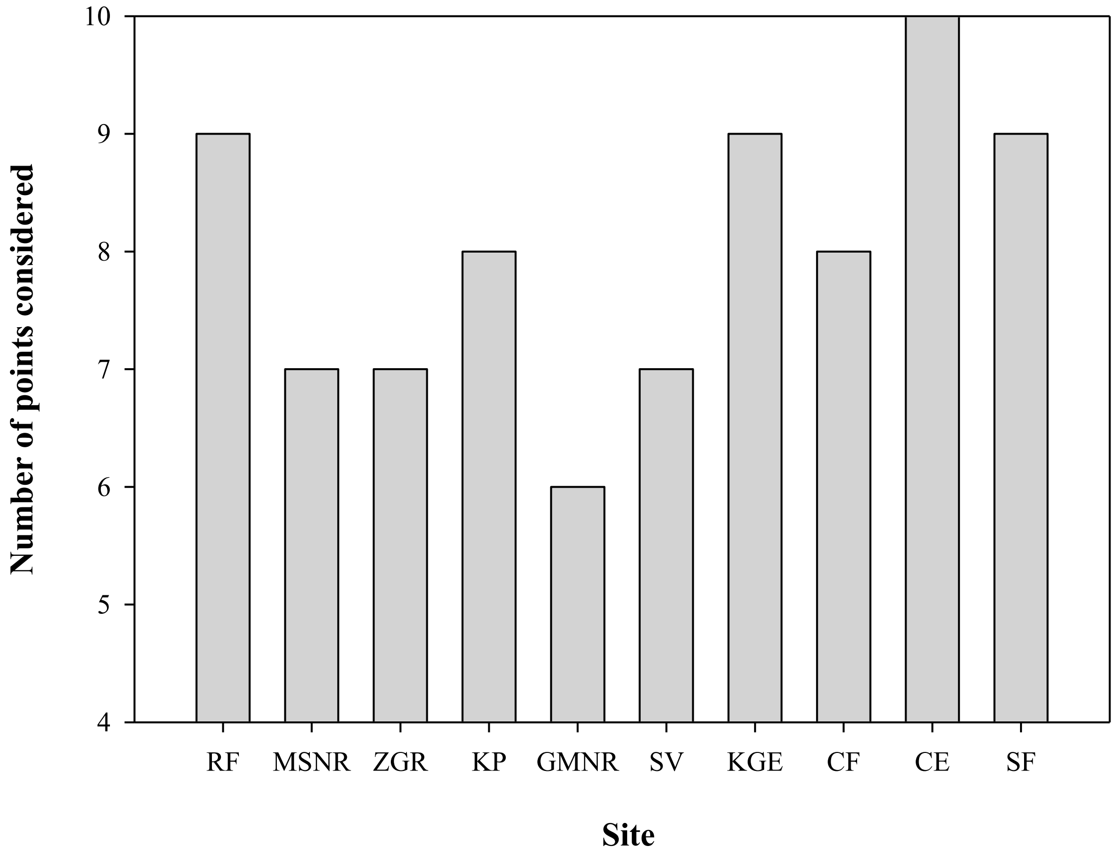

Figure 3.2: The number of criteria that were considered by each site (N = 10 sites). Site names: RF (Roselands Farm), MSNR (Michaelhouse School Nature Reserve), ZGR (ZuluWaters Game Reserve), KP (Kusana Park), GMNR (Gelijkwater Mistbelt Nature Reserve), SV (Sani Valley), KGE (KwaWula Game Estate), CF (Colesport Farm), CE (Cathkin Estate), SF (Stonehaven Farm).

Population growth rate increased as landowners considered more criteria prior to relocating oribi (Figure 3.3). This highlights the importance of following a basic set of criteria to increase the chance of successful relocations. However, as this trend only explains a certain amount of variation ($r^2 = 0.297$), I explored other variables in addition to the 10 criteria that could potentially influence oribi population growth rates.

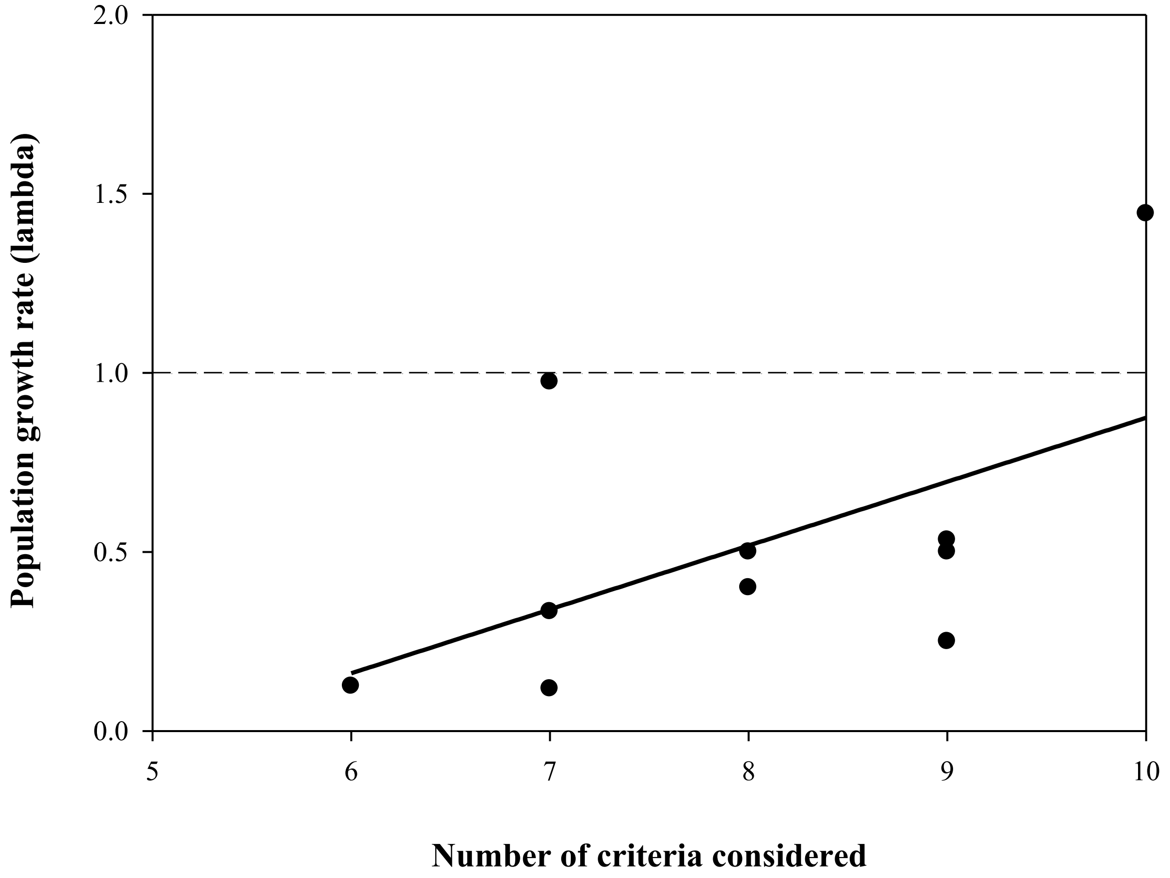

Figure 3.3: Relationship between the number of criteria considered and population growth rate (λ) across relocation sites (N = 10 sites) (r^2 = 0.297) in KwaZulu-Natal.

Table 3.1: Perceived reasons from landowners/managers for the success/fail of oribi relocations conducted in KwaZulu-Natal (N = 10 sites).

Site name	Size of land (ha)	Suitable habitat available (ha)	Number & composition of individuals relocated	Number of oribi after relocation	Number of oribi in final year	Number of years post-release	Population trend
1. Gelijkwater Mistbelt Nature Reserve	800	800	2M + 2F	4	0	2	Decreasing
2. Sani Valley Lodge	760	610	1M + 2F	3	0	3	Decreasing
3. Roselands Farm	1153	753	1M	12	2	10	Decreasing
4. Michaelhouse School Nature Reserve	230	90	2M + 5F	14	2	5	Decreasing
5. Kusana Park	340	320	2M + 3F	12	6	2	Decreasing
6. KwaWula Game Estate	220	150	1	5	3	5	Decreasing
7. Colesport Farm	143	70	3M + 3F	10	4	2	Decreasing
8. Stonehaven Farm	800	500	7 and 4 and 2	14	7	7	Decreasing
9. ZuluWaters Game Reserve	3153	1630	4M + 11F	39	38	8	Stable
10. Cathkin Estate	1090	350	1M + 3F	9	13	5	Increasing

Factors influencing oribi population trends/relocation success

The model that provided the best fit to the data (Model 12; Table 3.2) included oribi population size, the amount of suitable habitat available, stocking rates of additional herbivores, and the interaction between suitable habitat available and stocking rates. Only one site had an increasing population growth rate, while small oribi populations (<18 individuals) at relocation sites had decreasing population growth rates (Figure 3.4). There was one large population (39 individuals) that had a stable growth rate (λ = 0.974). This point is accountable for the high variation observed at populations >18 individuals (Figure 3.4).

With regards to the effect of the availability of suitable habitat on population growth rates, the majority of the sites that had <800 ha of suitable habitat had decreasing growth rates (Figure 3.5). However, the one increasing population had 350 ha of suitable habitat available. As the populations decreased at a majority of the sites, it is not possible to determine the population size as well as the amount of suitable habitat that is required for oribi relocations to be successful. This is made even more complicated by the high variance that was recorded. However, it could be that larger relocated populations (Figure 3.4) with greater availability of suitable habitat (Figure 3.5) can overcome the 10 criteria not being considered. This, however, would need to be explored further. Furthermore, based on the trend line, even though the majority of populations had decreasing growth rates, growth rates were lower when stocking rates of other herbivores were low (>3.5 ha/AU) compared to when they were high (<3.5 ha/AU). However, the variance along this trend line was high making it difficult to draw any conclusions (Figure 3.6).

Moreover, there was a significant interaction between suitable habitat available and stocking rates and their influence on lambda (Figure 3.7). Specifically, when there was more than 800 ha of suitable habitat available and high stocking rates (<3.5 ha/AU), oribi experience high population growth rates (λ>1, peak 1: shown as green and yellow and peak 2:

shown as green, yellow and orange in Figure 3.7). However, as the availability of suitable habitat increased, and stocking rates decreased, oribi population growth rates decreased ($\lambda<1$, shown as blue in Figure 3.7). Ultimately, the highest oribi population growth rates were achieved when the suitable habitat availability was more than 800 ha and stocking rates in this study were high (<3.5 ha/AU) (Figure 3.7).

Table 3.2: Results of model selection procedure to assess the different factors influencing oribi population trends and growth rates

	Factors included in the model	Number of parameters	AICc	ΔAICc	AICc weight
1.	Population size	3	9.776	10.740	0.002
2.	Suitable habitat available	3	10.290	11.254	0.002
3.	Stocking rates	3	8.886	9.850	0.003
4.	Population size, suitable habitat	4	11.636	12.600	0.001
5.	Population size, suitable habitat, interaction	5	11.010	11.974	0.001
6.	Population size, stocking rates	4	10.331	11.295	0.002
7.	Population size, stocking rates, interaction	5	10.831	11.795	0.001
8.	Suitable habitat, stocking rates	4	10.112	11.076	0.002
9.	Suitable habitat, stocking rates, interaction	5	4.837	5.801	0.026
10.	Population size, suitable habitat, stocking rates	5	12.106	13.070	0.001
11.	Population size, suitable habitat, stocking rates, population size x suitable habitat	6	12.643	13.607	0.001
12.	**Population size, suitable habitat, stocking rates, suitable habitat x stocking rates**	**6**	**-0.964**	**0.000**	**0.465**
13.	Population size, suitable habitat, stocking rates, population size x suitable habitat, population size x stocking rates	7	10.116	11.080	0.002
14.	Population size, suitable habitat, stocking rates, population size x suitable habitat, suitable habitat x stocking rates	7	0.164	1.128	0.265
15.	Population size, suitable habitat, stocking rates, population size x suitable habitat, population size x stocking rates, suitable habitat x stocking rates	8	1.312	2.276	0.149
16.	Population size, suitable habitat, stocking rates, population size x suitable habitat, population size x stocking rates, suitable habitat x stocking rates, 3-way interaction	9	2.580	3.544	0.079

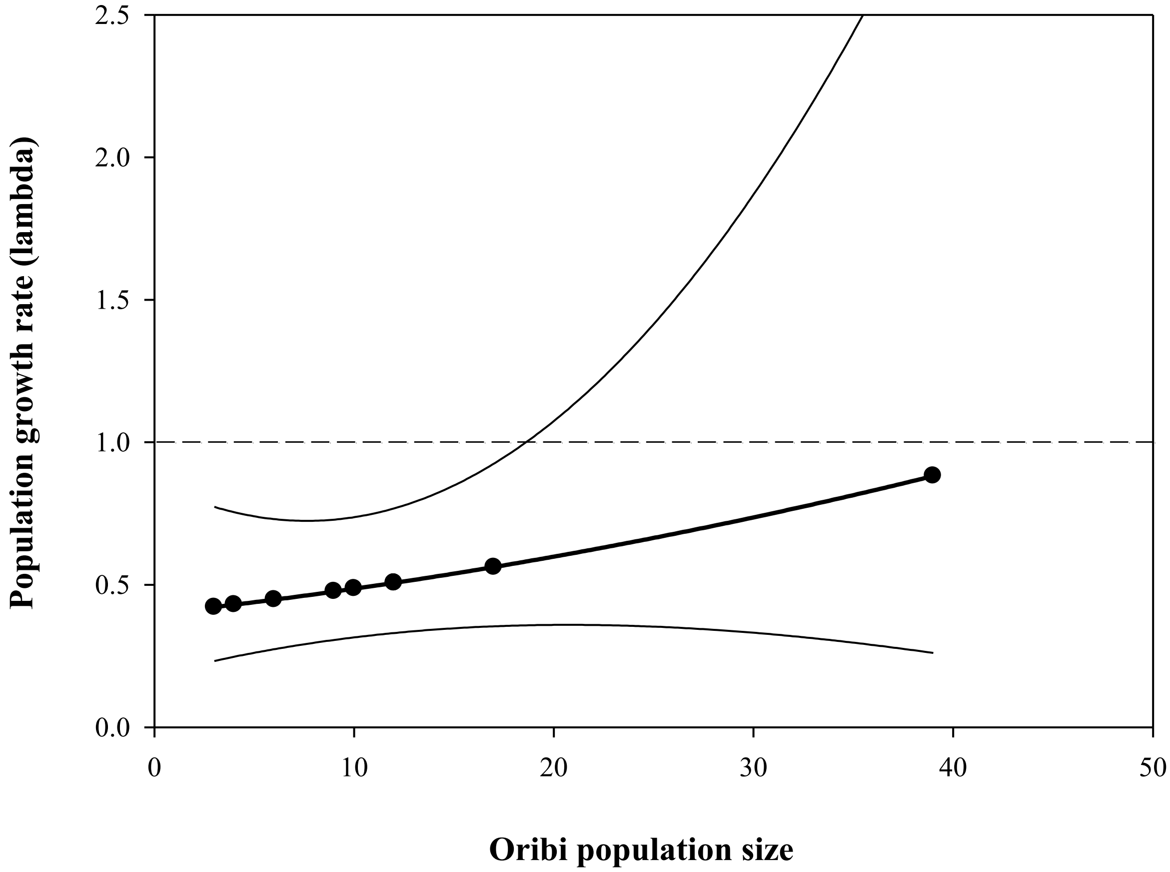

Figure 3.4: The influence of oribi population size on population trends (λ) for relocation sites (N = 10) in KwaZulu-Natal. The bold solid line represents the trend line with 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

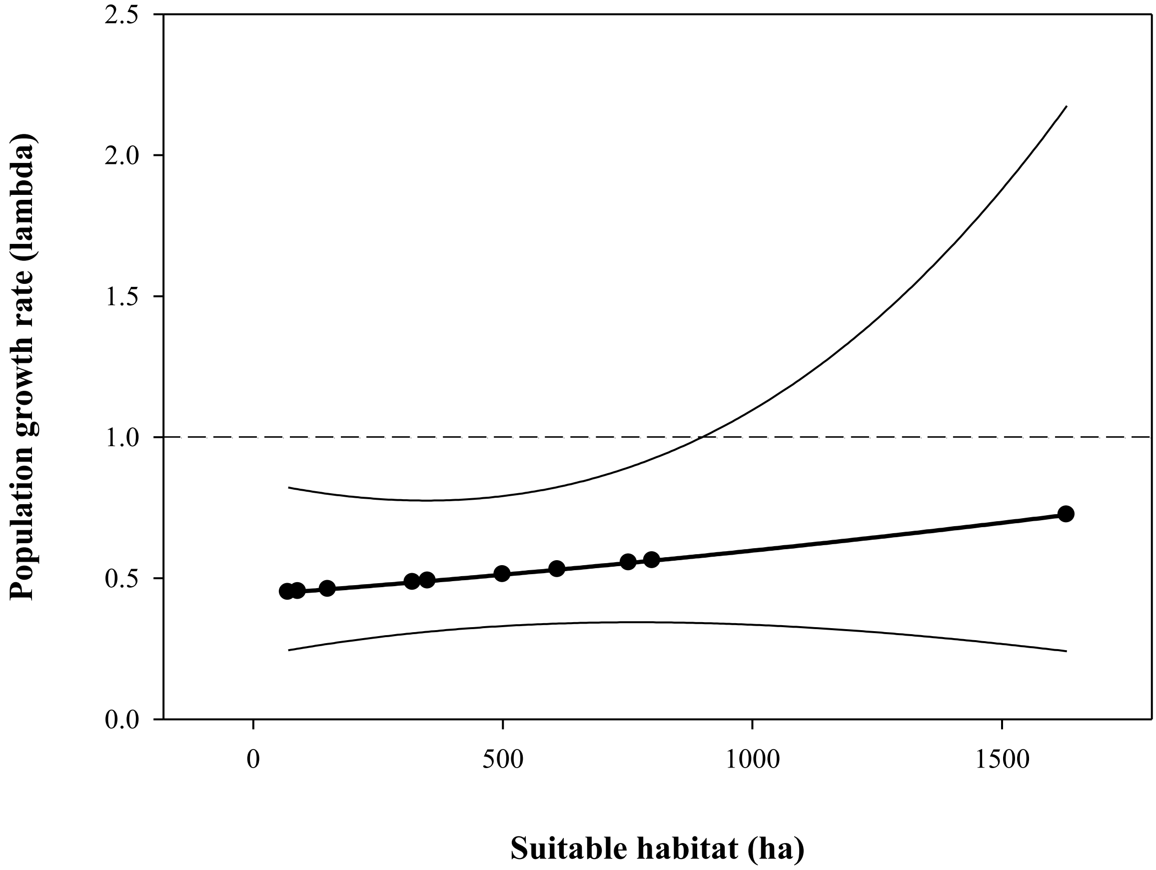

Figure 3.5: The influence of suitable habitat available on population trends (λ) for relocation sites (N = 10) in KwaZulu-Natal. The bold solid line represents the trend line with 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates.

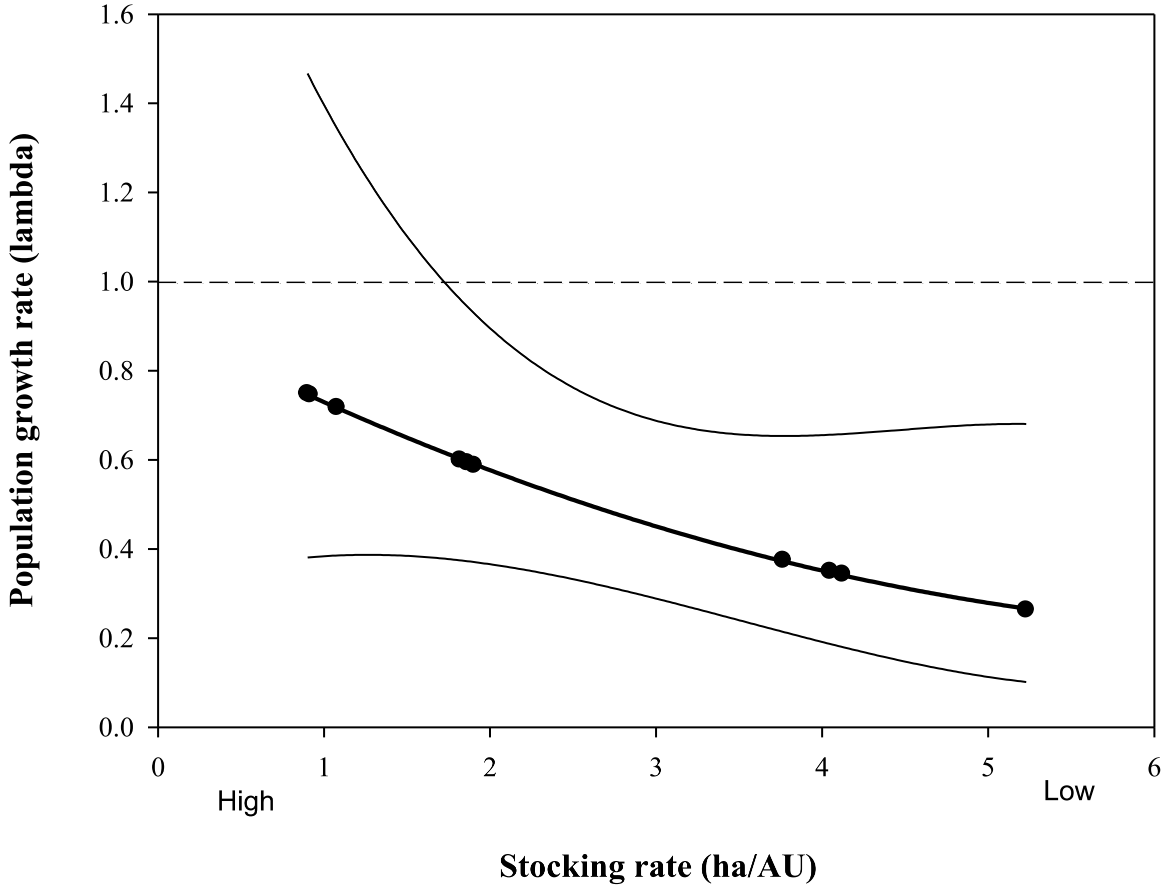

Figure 3.6: The influence of stocking rates on population trends (λ) for relocation sites (N = 10) in KwaZulu-Natal. The bold solid line represents the trend line with 95% confidence intervals (thin solid lines). When λ = 1, populations have stable growth rates. Values below 1 represent decreasing population growth rates and values above 1 represent increasing growth rates. Stocking rates of >3.5 ha/AU are classified as low, and those <3.5 ha/AU are high stocking rates.

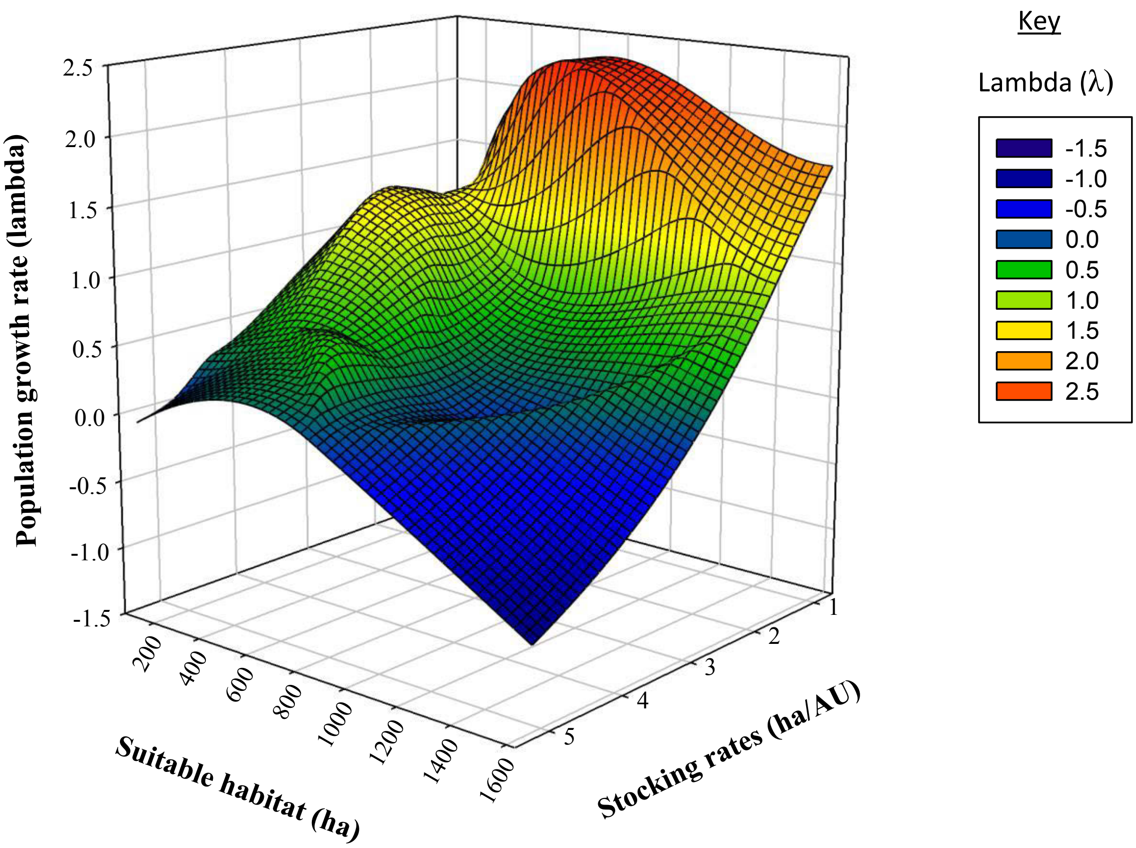

Figure 3.7: 3D mesh diagram representing the interaction between suitable habitat (ha) and stocking rates (ha/AU) and their influence on lambda (λ). When λ = 1, population growth is stable.

Discussion

This study highlights the importance of considering a number of relocation criteria prior to moving oribi into new areas. Specifically, many of the important criteria were not considered prior to the relocation of oribi to some of the sites. As a result, it is not surprising, that the only site that showed an increasing oribi population after the introduction of oribi, is the one that happened to consider all ten criteria. Seven criteria were considered by the stable population. The chance of success increased when landowners considered more criteria. This suggests that relocation can be used as a conservation tool for oribi in South Africa, provided that initial assessment criteria are considered. Moreover, the results indicate the importance of monitoring relocation projects. Long-term post-release monitoring plans are severely lacking from many of these relocation sites. Upon exploring the specific variables that may influence oribi population trends at relocation sites, I found that oribi population size (including the relocated individuals), the amount of suitable habitat available, stocking rates of additional large mammalian herbivores (e.g. cattle, wildlife), and the interaction of suitable habitat and stocking rates significantly influenced population trends. The majority of small populations (<18 individuals) had decreasing growth rates. In addition, when the availability of suitable habitat was below 800 ha, the majority of oribi populations decreased. Furthermore, somewhat counterintuitively, high stocking rates (<3.5 ha/AU) of additional mammalian herbivores resulted in higher oribi growth rates compared to low stocking rates (>3.5 ha/AU), although the majority of populations displayed decreasing growth rates. The highest growth rates for oribi populations were found when the amount of suitable habitat available was more than 800 ha and when stocking rates were high in this study.

Pérez et al. (2012) found that most relocation projects do not address key criteria prior to a relocation, resulting in inadequately designed relocations that have a high potential for failure. Despite not being aware of these criteria prior to the relocation, this was true for the majority of my sites. In my study, only one site had considered all 10 of the criteria points, and that resulted in an established population with an increasing growth rate. The remaining sites did not consider all the points, and failed to establish successful viable populations. Even though this is only a sample size of one, it does provide some degree of support to the idea of utilising criteria prior to conducting oribi relocations. This can save valuable effort and money, which could be put to better use for conservation purposes.

For the 10 oribi relocations to date, the majority of the populations (i.e. 90%) were small (<18 individuals) with decreasing growth rates. Moreover, these populations had less than 800 ha of suitable habitat available. These decreasing population growth rates can likely be explained by majority of the study sites being too small to accommodate appreciable oribi numbers, especially since males can hold territories of up to 60 ha. Because there was only one large study area with a large number of oribi (N = 39 individuals), the models analysed were not balanced in terms of population sizes and habitat availability.

However, even though it is a sample size of one, an increasing growth rate was observed for the site that had a small population size (9 oribi) and access to little suitable habitat (350 ha). This is somewhat counter-intuitive, as one would expect a small population with access to large amounts of suitable habitat to grow (see Chapter 2). However, the fact that this relocated population was successful lends support to the importance of considering and meeting all criteria prior to the relocation of oribi. Yet, the one large population (39 oribi) with a high availability of suitable habitat (1630 ha) had an almost stable growth rate. It however, only considered seven criteria. This could suggest that the introduction of larger oribi populations with access to greater availability of suitable habitat can overcome not considering all 10 criteria. Furthermore, results from Chapter 2 suggest that populations with access to more suitable habitat tend to have increasing growth rates. This, however, would need to be explored further before any firm conclusions could be drawn.

Oribi are the smallest African grazing antelope. Hence, they are under immense pressure with regard to ingesting high quality food (Adamczak and Dunbar 2007, Stears 2015). As a result, if landowners are keen to maintain oribi on their property, they need to manage and maintain suitable grasslands. Suitable grassland for oribi requires a mosaic of tall and short grass. In Chapter 2, I found that oribi populations that had increasing growth rates had access to >600 ha of suitable habitat (see Figure 2.7). For relocations, greater success required access to >800 ha of suitable habitat (see Figure 3.5). This may reflect the tendency for newly released herbivores to wander over large areas, and thus require greater space and access to resources (Berger-Tal and Saltz 2014). Relocated animals require more space because they need to explore their new environment in order to gain knowledge about available resources, predators, and mates (Berger-Tal and Saltz 2014). However, the difference in the amount of suitable habitat required for higher population growth rates may be due to the smaller sample size of the relocation events (N = 10 relocations) generating different results to the ones generated using the larger sample of oribi populations that had adequate returns (N = 25 populations) (see Chapter 2).

One way of managing grasslands is by managing stocking rates. Stocking rates influence grassland heterogeneity, which will ultimately affect whether oribi have the necessary resources (e.g. the quality and availability of food) and shelter that they require from predation (Stears 2015). Oribi require short grass for feeding. Moreover, they need tall grass for concealment of their young, cover from predators, and feeding (Smithers 1983, Everett et al. 1991). Without correct habitat management, oribi will lack sufficient habitat heterogeneity, and thus populations may decline. Grazing can influence the spatial heterogeneity of vegetation and reduce food availability (Adler et al. 2001, Stears 2015). High stocking rates are generally thought to result in competition between species because of habitat degradation (O'Reagain and Turner 1992, Derner et al. 1994). In addition, Griffith et al. (1989) found that potential competition reduced the success of relocations.

Along these lines, Stears (2015) found that at high stocking rates (0.95 ha/AU) during the wet season, oribi had to adjust their feeding and focus on green leaves in taller grass swards, which were not used by cattle. Moreover, the high levels of wet season grazing by the cattle reduced the availability of high quality grass for oribi in the dry season ultimately reducing their nutritional intake (Stears 2015). However, the results of my study indicate that low stocking rates of other large herbivores result in lower oribi population growth rates compared to high stocking rates. This pattern may be due to the other herbivores providing limited to no facilitation for oribi. Specifically, the foraging of one herbivore species can facilitate other herbivores (Makhabu et al. 2006, Stears 2015). This is generally via increasing vegetation regrowth that is high in nutrients and low in fibre (Arsenault and Owen-Smith 2002).

With regard to the interaction between the availability of suitable habitat and stocking rates, the highest oribi population growth rates were observed when the availability of suitable habitat was more than 800 ha and stocking rates were at a high level. In addition, the one successful relocation site had a high stocking rate of other herbivores. It seems counter-intuitive that oribi populations would do better when stocking rates of other herbivores were high. However, it may be that the high stocking rates resulted in a higher degree of grass heterogeneity and potentially greater availability of high quality grass regrowth than low stocking rates. For example, Stears (2015) found that during the wet season oribi that fed in areas containing cattle, had higher nutritional gain than those that fed in areas without cattle. This was due to the foraging of the cattle stimulating high quality grass regrowth that the oribi could then eat (Stears 2015). Alternatively, it may be that the high stocking rates in these introductions were not high enough such that the other herbivores actually competed with oribi for food. If this were the case, then there may have been limited competition between the species.

As suitable habitat increased, and stocking rates decreased, population growth rates decreased. This may again be explained by a lack of facilitation for oribi, resulting in a decrease in habitat heterogeneity (e.g. more tall grass), and potentially a reduced availability of high quality grass regrowth. It is likely that high quality habitat may result in higher population growth rates, and greater relocation success (Griffith et al. 1989).

The high variance observed around the relationship between oribi population growth rates and 1) population size, 2) availability of suitable habitat, and 3) stocking rates suggests that these three variables only influence growth rates to a certain degree. There are likely other factors that play a role in driving these growth rates and influencing relocation success. These may include factors such as, 1) their digestive systems and gut microflora needing time to adjust to the vegetation of the new habitat (Sinclair et al. 2006), 2) different stocking rates under the different grazing regimes, 3) the spatial scale at which suitable habitat is made available (Stears 2015), 4) the effect of predators, and 5) the effects of poaching and illegal dog hunting. Furthermore, the high variance could have been attributed to sample size and population sizes, as all tested populations were small.

A further explanation that could have influenced the growth rates of the populations is the Allee effect. The Allee effect is a decrease in population growth rate at low densities (i.e. the fitness of an individual is affected by the density of conspecifics) (Kuussaari et al. 1998, Stephens et al. 1999, Fowler and Ruxton 2002). It is possible that the population sizes of the relocated individuals was too low, which resulted in the majority of the populations to decrease (Courchamp et al. 1999). However, if this were the case, we would expect all the small populations to have declined, while any large populations should have increased. This was not the case. The one successful population (i.e at Cathkin Estate, Table 3.1) comprised a small population of only nine individuals initially. Yet, it experienced an increasing population growth rate. In addition, due to their territoriality, oribi density generally does not get very high (Jarman 1974, Everett 1991). Thus, populations of 14 individuals likely represent intermediate sized oribi populations. If this is the case, then if these patterns are driven primarily by the Allee effect, I would expect some of these intermediate populations to be increasing. However, this did not happen. Moreover, the largest initial population of oribi (N = 39 individuals) (i.e. ZuluWatersGame Reserve) remained stable. This, however, may be due to this population filling the available space, and thus there being a lack of space for the population to move into and grow. Either way, the overall pattern does not seem to indicate that the Allee effect was a key driver behind the success or failure of these different populations.

With regard to the model selection for my data, I used the model with the lowest AICc value as it provided the most parsimonious fit. However, models that have a difference of less than 2 AICc units have similar support for the data (Burnham and Anderson 1998). Table 3.2 indicates that there are three models (Models 12, 14 and 15) of AICc differences of <2 indicating that they were equally parsimonious. As a result, all three of them could potentially be used to analyse the data. However, I chose to use model 12 (population size, suitable habitat, stocking rates, suitable habitat x stocking rate) because it was the model that had the lowest AICc value. In addition, model 12 had the highest AICc weight value (i.e. the highest chance of being the best model fit) and it was the model with the fewest number of parameters out of the three potential models.

It is risky to relocate endangered animals. Griffith et al. (1989) found that relocations of native game species were more successful than endangered or threatened species. For endangered or threatened species, when populations are decreasing and density is low, relocation success is generally low. Relocations should therefore be considered before populations start to decline and not as a last resort (Griffith et al. 1989). In addition, relocations into historical ranges were more successful than those outside of historical ranges (Griffith et al. 1989). Four of the 10 sites that received oribi in this study did not have any oribi prior to the relocation. Not surprising, none of these were successful. Even though these sites may fall within the historical range of the species, to increase the chance of success, oribi should be moved to areas where successful populations are known to have occurred previously.

However, a number of oribi populations across South Africa are small and are at a risk of being 'doomed' populations (i.e. populations that will disappear due to complete removal of their habitat). Therefore relocating these animals is the only way to increase their chance of survival. As a result, the small success recorded to date is still a success, but it can be improved through the findings of this research. Due to the overall reduction in oribi habitat, relocation of individuals is a necessary conservation tool for oribi. The one successful relocation suggests that these conservation goals can be achieved with the appropriate management decisions. These management decisions should include relocating oribi into more suitable habitat areas.

Even with a low success rate, relocating animals is a popular form of conservation for many species. Successful relocations tend to have good publicity because popular species are more favourable in media (Dodd and Seigel 1991). In addition, authors are more likely to publish results if they are able to report a 'success' (Fischer and Lindenmayer 2000). Success of relocation are generally examined at a specific point in time – shortly after release (~1 year), as long-term monitoring is time consuming and expensive (Jule et al. 2008). This has been neglected with most relocations. Therefore, this is just perceived success. It lacks long-term monitoring and there is inadequate information on failures (Dodd and Seigel 1991). In contrast, this study includes some long-term relocation data (i.e. 5-10 years), although there is some vital information missing. There are some sites that have shorter durations (i.e. 2-3 years post-release), which likely influences the results of this study. For example, there could be factors during these few years, such as low or high rainfall, which may influence food availability and result in a population decrease or increase respectively. Moreover, yearly differences in predator numbers or poaching events may also greatly influence the growth rates of these relocations. However, a better understanding of the factors that result in successful relocations can be enhanced through better monitoring (Guy et al. 2015), better financial accountability and even publishing results that are unsuccessful (Griffith et al. 1989). It is important to emphasize the need to address key criteria prior to the relocation of any species (Dodd and Seigel 1991, Pérez et al. 2012). Considering these points would likely increase success rates, and thus make relocations an important conservation strategy for a variety of different animals (Kleiman 1989).

Because oribi are vulnerable, their conservation is necessary. The results of this study highlight that the survival of oribi and the success rate of relocations are strongly influenced by management decisions prior to the relocation, as well as long-term decisions made after relocation. As doomed populations have to be relocated, considering all the relocation criteria prior to moving animals may increase success. If this is done, then relocation could play a much larger role in the successful conservation of oribi in South Africa.

Chapter 4
Conclusion and Management Recommendations

Section I: Conclusion

The broad aim of this project was to determine the population dynamics and relocation success of oribi (*Ourebia ourebi*) in KwaZulu-Natal. Because oribi are listed as vulnerable, I wanted to determine whether relocations could be used as a viable conservation tool in South Africa. To address these aims, I set up the following objectives: 1) determine the distribution of oribi population trends throughout KwaZulu-Natal, 2) explore the factors that drive these different trends across the province, and 3) determine the success rate of previous oribi relocations and the factors influencing their success.

The population dynamics of oribi are poorly understood (Shrader et al. In press). In addition, the factors that drive oribi populations to increase, decrease, or remain stable had not previously been addressed. To explore these gaps, I focused Chapter 2 on oribi population trends and their distribution across KwaZulu-Natal. To successfully conserve oribi, it is important to determine what factors are driving these trends. My study highlights the importance of initial population size and the amount of suitable habitat available as factors that drive oribi population trends. For oribi, habitat suitability can be determined by grazing regime. I found that grazing regime interacts with initial population size and the availability of suitable habitat. A key finding of this study is that intermediate initial oribi population sizes are more likely to have increasing growth rates. In addition, populations with a high availability of suitable habitat (>600 ha) have increasing growth rates.

Chapter 3 builds on from the results obtained from Chapter 2. Because the majority of oribi populations in KwaZulu-Natal are decreasing, and some populations are doomed, relocations have been conducted over the years as a conservation strategy. However, there is no information regarding the success of these relocations in terms of creating viable oribi populations. Interestingly, I found a relocation success rate of only 10% (N = 1 relocation). One reason for this low success rate is that no strict protocol had been followed with regards to choosing potential relocation sites. When I applied 10 key criteria to each site, I found that only one site addressed all the necessary criteria prior to the relocation. As in Chapter 2, population size and suitable habitat availability were key factors that influenced population trends across these relocation sites. Small populations of less than 18 individuals that had <800 ha of suitable habitat available showed decreasing population growth rates, with the exception of the one successful site. This site had nine oribi and 350 ha of suitable habitat available. The increasing growth rate for this site was likely because all criteria from the guidelines were met prior to the relocation. Furthermore, I found that high stocking rates of other large herbivores resulted in higher oribi population growth rates than areas with low stocking rates. However, both stocking rates had decreasing growth rates. Long-term post-release monitoring is severely lacking from many of the relocation sites. Long-term monitoring is extremely important in determining success or failure of oribi relocations.

For both studies (Chapter 2 and Chapter 3) however, high variance for each of the factors influencing oribi population growth rates were observed. This suggests that the sample sizes may have been somewhat small. However, it also suggests that these variables only explain a small portion of the variation associated with the observed oribi population trends and growth rates. Therefore, there are likely other factors that influence these population trends and growth rates. For example, in Chapter 1, different stocking rates under the different grazing regimes, and the spatial scale at which suitable habitat is made available to oribi could influence growth rates. In addition, in Chapter 2, allowing their digestive systems and gut microflora to adjust to the vegetation in the new habitat could also influence oribi population growth rates. However, for oribi, some of these other factors are difficult to quantify. For example, the impact of illegal dog hunting on oribi populations is a major cause for concern (Magwaza and Little 2014), and it is difficult to get an accurate measurement of the direct effect it has on oribi populations (i.e. how many individuals are killed every year on the same property due to poaching). Furthermore, predators are perceived to be a major threat to oribi. Yet, like poaching, deaths as a result of predators are also difficult to quantify.

To develop an accurate understanding of how these factors influence population dynamics (i.e. population growth), it is important to know how many individuals are killed by predation and poaching each year. However, long-term data for predation and poaching are not available. In addition to these two factors, there is not a lot of long-term data available to determine what drives oribi population dynamics.

The results of this study are not only useful for the management and conservation of oribi populations in KwaZulu-Natal, but they can be used for oribi populations across South Africa. Furthermore, these findings can be applied to other threatened or endangered large mammalian herbivores. Large mammalian herbivore conservation is important as herbivory shapes the structure, diversity and functioning of many terrestrial ecosystems (Gordon et al. 2004). Regardless of the species being relocated, this study highlights the importance of considering basic criteria to ensure higher successful outcomes. In addition, it is crucial to understand the population dynamics of a specific species in order to successfully manage and conserve them.

Section II: Limitations of working with a database

Despite having an extensive database from which to draw on, I found that the database contained many limitations that reduced the available sample size and ultimately prevented a more detailed analysis of oribi population trends. For example, one of the key limitations was that data from each site had not been submitted consistently from year to year. As a result, many sites had large gaps in the estimates of oribi numbers. In addition, there were inaccurate and inconsistent data entries into the database, which I needed to sort out prior to my analyses. These included problems with the correct names of farms (i.e. the same farm being entered as two separate farms), incorrect names and surnames of the landowners, outdated telephone numbers, and wrong GPS positions of farms. This incorrect contact information led me to not being able to contact many farmers to obtain management information, which ultimately reduced my sample size. Moreover, there was a great deal of duplicated and incorrect data (e.g. identical farm, but allocated different site ID). Additionally, information of the division of properties into multiple farms or the expansion of properties from farmers buying neighbouring farms were not recorded.

From working with the database, I believe that some additional information needs to be obtained from each farm. This may simply be obtained by incorporating relevant questions on the survey forms. For example, the size of the farm is missing for many sites. In addition, the area of grassland for oribi is missing. This information would be useful as it would allow oribi densities to be calculated and would greatly expand the analytical power of the data. Furthermore, information on whether farm sizes have increased, decreased or remained the same would allow the same calculations. Finally, information on the different land uses on each farm (grazing, plantations, crops) is also missing. Adding in these factors would then allow us to better understand oribi population dynamics and put relevant conservation actions into place.

Another key shortcoming of the database was that data from Ezemvelo KZN Wildlife reserves were not entered into the database prior to 2013. Although most oribi populations are found within privately owned land, including reserve data is a crucial feature that affects overall oribi numbers. As the initial purpose of the database was to keep up to date with oribi numbers in South Africa, KZN Wildlife reserve data must be added in every year. Hence, I inserted these data prior to my analyses.

With regard to population dynamics, there is a general lack of information concerning birth rates and death rates on oribi in general (Shrader et al. In press). This is also true in the database. Only total numbers are given for each farm. This is useful for determining total population number. However, it is also important to know how many of the individuals recorded each year consisted of males, females, and new-borns. This would allow birth rates to be calculated. In addition, death rates are notoriously difficult to calculate (Krebs 2009, Pringle 2010). Without good information, it is unclear whether declines in population numbers are due to individuals dying, inaccurate counts, or individuals dispersing to neighbouring farms. This highlights the importance of obtaining more accurate information to allow a more detailed analysis of oribi population dynamics (i.e. natality, mortality, immigration, and emigration).

Section III: Limitations of using questionnaires

In general, there are limitations and potential problems of data obtained from questionnaires (Munn and Drever 1990, Brown 2002). Even though questionnaires can be sent to a large number of people at low cost (Brown 2002), the response rate is generally always low and this ultimately influences sample sizes (Dillman 2000). For this reason, questionnaires should be kept short (i.e. using close-ended questions) and they should not be time-consuming, otherwise respondents will not co-operate (Porter 2004). The Oribi Working Group's survey questionnaire is structured in such a way that it is not time-consuming to fill out and has the basic information included (see Appendix 1).

Questionnaires can be reliable if they are constructed and conducted well. They have the ability to produce straightforward descriptive information (Munn and Drever 1990).

However, some close-ended questions (e.g. yes/no responses) lack validity as no further explanation is given (Munn and Drever 1990, Brown 2002). Therefore, questionnaires cannot tell us about the context and meaning behind a response (Brown 2002). This is a potential problem with the oribi questionnaire. As most of the questions are close-ended, it is difficult to identify how much thought has gone into these responses, and there is no way to tell how truthful they are (likelihood of socially desirable responses to certain questions). In addition, detailed information is missing from the oribi questionnaire. As discussed in the previous section, more accurate information will allow a better understanding of oribi population dynamics and thus, better management of populations.

Furthermore, people may misinterpret a question and also interpret questions differently. For example, what is ‘low’ to one respondent may be ‘medium’ to someone else. With regard to the oribi questionnaire, landowners may not know the population trend and may guess as to whether populations are increasing, decreasing or remaining stable. This level of subjectivity alters the validity of the data. This should be taken into consideration when using questionnaires in research studies.

Section IV: Management recommendations

Understanding the population dynamics of a species is important in many conservation and management decisions (Sinclair et al. 2006). Moreover, identifying which factors drive animal populations to increase or decrease is essential in determining how they are managed (Gordon et al. 2004). Therefore, good management decisions and practices are required when managing any species. For oribi, good management of grasslands and other herbivores is vital in order to sustain existing populations and to ensure higher relocation success rates. Using the results from Chapters 2 and 3, I have generated the following management recommendations:

For existing oribi populations

1. Initial population size – as small initial populations (<14 individuals) display both increasing (due to sufficient resources available) and decreasing population growth rates (due to their susceptibility to change), it is recommended that oribi populations initially start off at an intermediate level (i.e. ~14-30 individuals). At this level, they would not have to compete for space, assuming that there is enough suitable habitat available, allowing the population to grow.
2. Availability of suitable habitat (i.e. the availability of heterogeneous areas of both short and long grass areas for feeding and cover from predators) – the more suitable habitat available, the higher oribi population growth rates will be. Oribi populations should be in areas with more than 600 ha of suitable habitat available. This ensures that they have enough resources such as forage and shelter as well as a sufficient amount of space to defend territories. However, as suitable habitat is based off estimations of landowners' perceptions, more rigorous measurements of habitat availability should be carried out.
3. Grazing regime – continuous grazing (i.e. feeding in one camp continuously) by existing herbivores (domestic/wild herbivores) is recommended for oribi, as this grazing system allows higher growth rates when compared to sites that had rotational grazing systems (i.e. when animals are moved between camps). However, stocking rates (suitable habitat available (ha)/number of animal units) should be considered as the impacts of high stocking rates may be greater than the benefits provided by a specific grazing regime.
4. Oribi surveys – landowners are encouraged to submit annual returns of their oribi population numbers. This will go a long way in helping the Oribi Working Group generate accurate oribi population estimates. Moreover, the inclusion of additional

information (e.g. age and sex structure), would provide key information that is missing. Furthermore, identifying increasing and doomed populations across the country will be useful in aiding future conservation strategies.

5. Monitoring populations – the only way to determine oribi population trends over a long-term period is to have a continuous monitoring system for individual populations. As the majority of oribi populations are found on private lands, it is up to individual landowners to manage and monitor their populations continuously. Apart from submitting annual returns, additional monitoring of animal movements as well as good management practices, should be applied. The Oribi Working Group should look to target a number of key populations (e.g. the 100 sites used in this study) and gather data from them each year. This will result in more accurate long-term oribi population trends.

For oribi relocations

1. Initial criteria – the 10 criteria from the guidelines set up by Pérez et al. (2012) have been shown to be important to follow prior to any relocation. Considering these criteria increases the chances of a successful relocation. By following these, especially when deciding on locations for doomed populations, would likely increase relocation success. Moreover, clear goals (i.e. to establish a viable population, long-term monitoring) of the project need to be set up prior to any decisions being made.
2. Population size – the majority of small populations have decreasing growth rates. Therefore, in support of the above results, it is recommended that intermediate population sizes are also considered for oribi relocations. However, if small populations need to be relocated, landowners must ensure that all basic criteria are considered and followed to increase the chance of success.

3. Availability of suitable habitat (i.e. the availability of heterogeneous areas of both short and long grass areas for feeding and cover from predators) – it is recommended that oribi are relocated to sites that have a high availability of suitable habitat (i.e. >800 ha). However, if this is not possible, they should at least be put into areas with access to more than 600 ha of suitable habitat, as the results from Chapter 2 suggest.
4. Stocking rates of other large herbivores (suitable habitat available (ha)/number of animal units) – because the majority of sites used in this study had decreasing population growth rates at both high and low stocking rates, it is recommended that stocking rates for these sites are kept at 3.5 ha/AU. Stocking rates are dependent on the habitat type and location. Therefore, for other sites, stocking rates should be kept at the recommended stocking rates, determined by the different Bioresource Groups from the Department of Agriculture. At these recommended levels, other large mammalian herbivores may facilitate oribi foraging and no competition may be observed.
5. Long-term post-release monitoring – to determine whether a relocation has been successful or not, long-term monitoring is essential. Post-release monitoring helps to identify whether the goals set initially are being met. It is extremely important to monitor animal populations directly after a relocation and for the long-term in order to be able to determine whether the project has been successful. Moreover, this will likely provide important data needed to generate an understanding on natality, mortality, immigration, and emigration.

Overall, the findings of this MSc have increased the understanding of oribi population dynamics in KwaZulu-Natal. The low success rate of oribi relocations to date is a cause for concern. However, the results of this study suggest ways of improving success, which can ultimately result in relocations being used as a successful conservation tool for oribi in South Africa.

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Appendix 1: Endangered Wildlife Trust Oribi Survey Form

ENDANGERED WILDLIFE TRUST
THREATENED GRASSLAND SPECIES PROGRAMME
conservation in action

ORIBI SURVEY FORM

Together SA CAN

Threatened Grassland Species Programme

2014 ANNUAL ORIBI SURVEY

Endangered Wildlife Trust

The Annual Oribi survey helps the Oribi Working Group make informed decisions about the conservation of the species. Please fill in this user friendly survey during September every year

Oribi Survey Information – please count Oribi anytime on your property between 1 and 30 of September 2014

Date Oribi counted:		No. of Male Oribi	
No. of Oribi counted (total):		No. of Female Oribi	
No. of groups counted:		No. of Juvenile	

Is your Oribi population (please circle): Stable Increasing Decreasing Not Sure

Are your Oribi under threat? YES NO

What factors are affecting your Oribi population?
Habitat loss – agriculture ☐ Habitat loss – afforestation ☐ Snaring ☐
Illegal shooting ☐ Organized dog hunting ☐ Stray dogs ☐
If other, please specify: ________________________________

Contact details -

Owners name:			
Owners telephone:		Cell phone:	
Owners email address:			
Owners postal address:		Code:	

Property details -

Property name:	
Magisterial district:	
Province	
Main farming activity/s	

Join the fight against hunting with dogs

SA CAN: Why as landowner you need SA CAN and their Family?

BECOME AN SA CAN MEMBER – FREE LIFETIME MEMBERSHIP

SA CAN has launched the first National Community 911 Incident Management Center (IMC) in the country. Comparable to the USA's 911, SA CAN's IMC links to 84 safety and security organizations, including the police, medical emergency services, fire & rescue services, private security and many more. One telephone number, or the push of a speed dial button on your cell phone, is what gains you access to this network of emergency help 24/7. SA CAN Halo Aviation ER24 has the only private Aeromedical Helicopter in KZN which is based at PMB. SA CAN IMC has joined hands with EWT, supported by KZN wildlife and has sponsored 637 Wildlife Officers across KZN. Jointly we are trying to unite SAPS, Wildlife Officers and Landowners into one centralised emergency and concerns communication hub. Whilst the focus is on illegal dog hunting, SA CAN has many others benefits for you the landowner. Given that it costs you nothing; can you afford not to join?

CLICK HERE TO REGISTER

Please return information to: **jibam@ewt.org.za**

PO Box 1312 Howick 3290

For more information : 033 330 6982/ 0825706977

Please pass on this survey form to your neighbours and advise if you need communication with your labourers/community on illegal hunting with dogs.

Appendix 2: Additional Questions for Landowners

1. Are the historical numbers indicated for your farm correct? Are there any missing years that you could fill in?
2. What is the size of your farm? Estimate in hectares (ha)
3. Has farm size increased/decreased over the years – if so, why?
4. What is the amount of suitable grassland habitat (a mosaic of long and short grass) for oribi? Estimate in hectares (ha)
    - How is your farm divided? Give proportions of grassland, rye grass, sugarcane, forestry, etc?
    - Do oribi use these habitats?
5. What type of farm is it? – dairy, beef, conservation, etc
6. What are the main threats to your oribi population?
7. What is your burning regime? Do you burn annually, every second year? Do you have fire breaks? Do you mow?
8. Do you have other grazers? If so, what species?
9. What type of grazing do you have? – continuous/rotational
10. What are your stocking rates? Rough estimate – has it increased/decreased over the years?
11. What type of fencing do you have? Are oribi able to move in and out of your farm?
12. What is the average rainfall per year? What is your winter rainfall? Is frost a problem?
13. Other comments

Appendix 3: Information collected from each relocation site during field visits

Name of site……………………………………………………………………………………

Private land/Protected area ………………………………………………………………..

Site ID (if site exists on oribi database)……………………………………………………...

GPS Coordinates………………………………………………………………………………..

Contact person………………………………………………………………………………..

Contacts details………………………………………………………………………………

Physical address of site………………………………………………………………………

Received ……………..…. oribi in …..……..……. from …………………………………………

Received ……………..…. oribi in …..……..……. from …………………………………………

Received ……………..…. oribi in …..……..……. from …………………………………………

Gave ……………..…. oribi in …..……..……. to ………………………………………………

Oribi numbers over the years:

Year	**Population Number**	**Year**	**Population Number**

General oribi population trend at this site……………………………………………………

Was the relocation in question, a success or fail……………………………………………

Main reason for the above……………………………………………………………………

Criteria points to look at before any relocation (Pérez *et al*., 2012) - were these points adhered to before oribi were relocated into the new habitat?

Necessity of the translocation

1. Is the species or population under threat?

2. Have the threatening factors been removed or controlled, or were they absent in the release area?
3. Are translocations the best tool to mitigate conservation conflicts?

Risk evaluation

4. Are risks for the target species acceptable?
5. Are risks for other species or the ecosystem acceptable?
6. Are the possible effects of the translocation acceptable to local people?

Technical and logistical suitability

7. Does the project maximize the likelihood of establishing a viable population?
8. Does the project include clear goals and monitoring? Goal is to establish a viable population and increase oribi numbers. Were there any long-term monitoring plans?
9. Do enough economic and human resources exist to support the translocation?
10. Do scientific, governmental, and stakeholder groups support the translocation?

Additional Questions

1. Confirm oribi numbers over the years – what is the general trend?
2. Size of farm/reserve
3. Has this size increased/decreased over the years? If so, why?
4. What is the amount of suitable habitat (grassland) for oribi? How is the farm divided? Estimate proportions.
5. What type of farm is it? Dairy, beef, sugarcane, etc.
6. What are the main threats to your oribi population? How bad are each of them, on a scale (low, medium, high)? What do you consider to be low, medium, high? E.g. Low = 3 oribi killed by poaching annually, etc.
7. How often do you burn? Annually/every 2nd year? Do you use firebreaks? How the firebreaks are placed – e.g. Perimeter breaks only, through the farm?

8. Do you mow parts of the farm?
9. What other game/grazers do you have?
10. What are your stocking rates? Has this increased/decreased over the years?
11. What type of grazing do you have – rotational/continuous? If rotational – how many camps do you have? Primary, secondary, resting camps? How often are cattle moved from one camp to the next? What is the height of the grass when cattle are moved to another camp? (Categorize).
12. What type of fencing do you have? Are oribi able to move in and out?
13. Has there been any major management changes over the years? Or anything that has changed to affect oribi numbers?