A GIS BASED HABITAT SUITABILITY ANALYSIS OF THE ORIBI ANTELOPE IN KWAZULU-NATAL

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Abstract

Geographic information systems and remotely sensed information provide an analytical platform for linking habitat features and animal distribution in a spatial context. The spatial culmination of such data using geographic information systems technologies is an important step towards providing information to decision makers on habitat suitability and the mapping thereof. Through the use of such techniques, environmental factors indicative of suitable habitat of the endangered oribi antelope were mapped within the extent of KwaZulu-Natal. The factors and individual weights were identified through multi criteria evaluation using analytical hierarchical process and expert knowledge. The resultant suitability indexed model provided a basis for cost distance procedures and was used to identify potential habitat corridors. An oribi conservation area network was created using these potential corridors and further cost distance functions. The Karkloof and Chelmsford conservation area networks reported the greatest concentrations of highly suitable habitat and therefore with reference to oribi specific habitat recommendations, draft management recommendations were collated.

Declaration

This study was undertaken in fulfilment of a Geography Masters Degree and represents the original work of the author. Any work taken from other authors or organisations is duly acknowledged within the text and references chapter.

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Andrew Hill

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Prof. Onisimo Mutanga
Supervisor

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Acronyms and Abbreviations

AHP	Analytical Hierarchical Processes
ANOVA	Analysis of variance
ANNTMP	Annual average temperature
ARC	Agricultural Research Council
BRG	Bio Resource Group
BRU	Bio Resource Units
CSIR	Council for Scientific and Industrial Research
CR	Consistency ratio
CAN	Conservation Area Network
CNR	Chelmsford Nature Reserve
DEM	Digital elevation model
DWAF	Department of Water Affairs and Forestry
ENM	Ecological Niche Modeling
EKZNW	Ezemvelo KZN Wildlife
EWT	Endangered Wildlife Trust
GIS	Geographic Information Systems
GPS	Global Positioning System
GRID	Raster File format
KZN	KwaZulu-Natal
KZNNCS	KwaZulu-Natal Nature Conservation Services
KNR	Karkloof Nature Reserve
PHVA	Population Habitat Viability Analysis
MAP	Mean Annual Precipitation
MCE	Multi-criteria evaluation
MCDA	Multi Criteria Decision Analysis
MAUT	Multi-attribute utility theory
NLC	National Land Cover (Programme)
NNR	Nqandu Nature Reserve
OWG	Oribi Working Group

Chapter One
Introduction

1.1 The problem and its setting

The cartographic representation of species occurrence patterns is a difficult endeavour. The distribution of plants and animals on the surface of the earth is regulated by a nearly infinite number of variables. These variables can be environmental or biological in origin and will simultaneously or independently influence the species distribution. "Maps can provide us with a detailed assessment of the distribution of species but the reality is that a comprehensive representation of the legitimate complexity of nature will be impossible without all the environmental and biological variables" (Miller, 1994, 26). The end result is that mapping the distribution of a species is near impossible without linking species distribution to habitat features. Geographic Information Systems (GIS) and remotely sensed information provide an analytical platform for linking habitat features and animal distribution in a spatial context. The spatial culmination of such data using GIS tools is an important step towards providing information to decision makers on habitat suitability and the mapping thereof.

Wildlife habitat suitability mapping and the connectivity of identified suitable habitat through GIS and remote sensing has greatly improved conservation and preservation methods over the past two decades. The speed and accuracy of habitat models have become well-accepted tools for understanding the habitat characteristics of different organisms, evaluating habitat quality and developing wildlife management strategies (Verner *et al.,* 1986). In today's world, the geographical locations of species occurrences are primarily a composite result of the impact of human civilization on environmental features (Miller, 1994).

The ability of animals to move across landscapes is critical at many scales. Animals need to be able to move efficiently within their home ranges to access food, shelter, mates and other basic needs (Stephens and Krebs 1986). Animals also need to be able to move beyond their home ranges to find unoccupied habitat and maintain genetic exchange between groups (Hanski and Gilpin 1997, Young and Clarke 2000). Landscape features can influence an animal's ability to move at both these scales. Although effects will vary for different species, major road networks, variable topography, human development, land cover types and land use types can all affect an animal's ability to successfully move through an area (e.g., Beier 1995, Brody and Pelton 1989, Gibeau and Heuer 1996, McLellan and Shackleton 1988). Understanding patterns of landscape permeability is particularly important for the conservation of species with home ranges under pressure from human development and low-density populations (Clark *et al.,* 1995, Noss *et al.,* 1999, Weaver *et al.,* 1996).

The extensive natural habitat contraction of oribi (*Ourebia ourebi*) is seemingly threatening the oribi species with extinction (IUCN, 2000). The oribi is an "endangered" antelope species where the latest census reports that there are less than 2600 individuals in KZN, of which 2000 individuals are on privately owned land and the remainder are in 16 Ezemvelo KZN Wildlife (EKZNW) reserves in KwaZulu-Natal. These concerns have brought about a plethora of literature and engaging investigations into the future of the oribi and its natural habitat by the Oribi Working Group (OWG). In a time span of 18 years, oribi antelope have disappeared from 25% of the farms they were previously found on (Marchant, 2000). This alarming finding was significantly overshadowed by the fact that there had been a 31% decrease in the total population numbers in KwaZulu-Natal. In 2000/2001 a further investigation revealed similar findings. Projections from habitat transformation modelling indicate that the grassland habitat of the oribi in KZN will likely disappear if no intervention is made. Everett (1991) evaluated the status and ecology of oribi populations occurring under a wide range of ecological conditions and management regimes. His work identified oribi specific habitat requirements and preferences within KwaZulu-Natal. Everett concluded that Oribi favour mesic grassland on flat to gently undulating terrain which is also the terrain best suited to agriculture and forestry (Everett, 1991). Oribi habitat and agricultural forestry land are therefore in direct competition to one another. The Oribi can therefore be considered an indicator species for the grassland conservation in general. Conservation of such habitat is highly contended by landowners and conservation authorities and a compromise must be reached for the species survival. The antelope is one of South Africa's most threatened species and its survival will depend on the continual research of the species and its habitat (IUCN, 2000).

1.2 The problem Statement and Scope of the Study

The dwindling numbers of oribi in KwaZulu-Natal have sounded warning bells to conservation authorities regarding the species survival. Faced with this dilemma the remaining oribi-suitable habitat is either unmapped and therefore unknown, or it is too fragmented to sustain viable oribi subpopulations (Marchant, 2000).

1.3 Aim and Objectives of the Study

In the light of the above discussion, this study set itself to the following aim and related objectives:

1.3.1 Aim

The aim of this project was to develop GIS based habitat suitability maps and suitable habitat linkages for oribi using several environmental variables identified in Everett's (1991) work and this GIS investigation.

1.3.2 Objectives

- To statistically establish environmental factors that best explain oribi distribution;
- To create oribi habitat suitability maps based on the environmental factors obtained in the previous objective;
- To create an oribi Conservation Area Network (CAN) through cost distance functions and algebraic expressions;
- To identify, using cost distance analysis, suitable habitat linkages between fragmented oribi populations in the oribi CAN's created in the above objective;
- To draft land management recommendations for two of the suitable habitat linkages identified in the above analysis.

This research project thus aimed to describe the habitat of the oribi, then quantify the habitat variables, ascertain habitat linkages and facilitate the development of conservation awareness in oribi habitat conservation

1.4 Structure of the thesis

The thesis is structured in the following format:

Chapter 2: A literature review of the relevant and useful literature to this study, including the specific habitat requirements of the oribi

Chapter 3: Details the sampling methods, field data collection procedure, CAN formation, proposed corridors and gives an overview of the data analysis

Chapter 4: Details the results of the statistical analysis, modelling procedure, CAN formation and proposed corridors

Chapter 5: Discusses the results and provides management recommendations

Chapter 6: Concludes the thesis and provides further recommendations

1.5 The Study Area

The study area of the project is the entire extent of the province of KwaZulu-Natal in Eastern South Africa (Figure 1.1). This area has an altitudinal variation ranging from sea level to 3400m, with a varying topography from coastal plains to sheer mountain slopes in the Drakensberg region. The rainfall of the region ranges from 500mm/year to 2000mm/year in which the diversity in rainfall and altitudinal variation gives rise to a diverse natural and man made vegetation structure. The vegetation of KwaZulu-Natal is highly diverse with Moist Coastal Forests, Thorn and Palm Veld (Camp, 1995) evident on the eastern sea board extending to the Montane Veld on the slopes of the Drakensberg in the west.

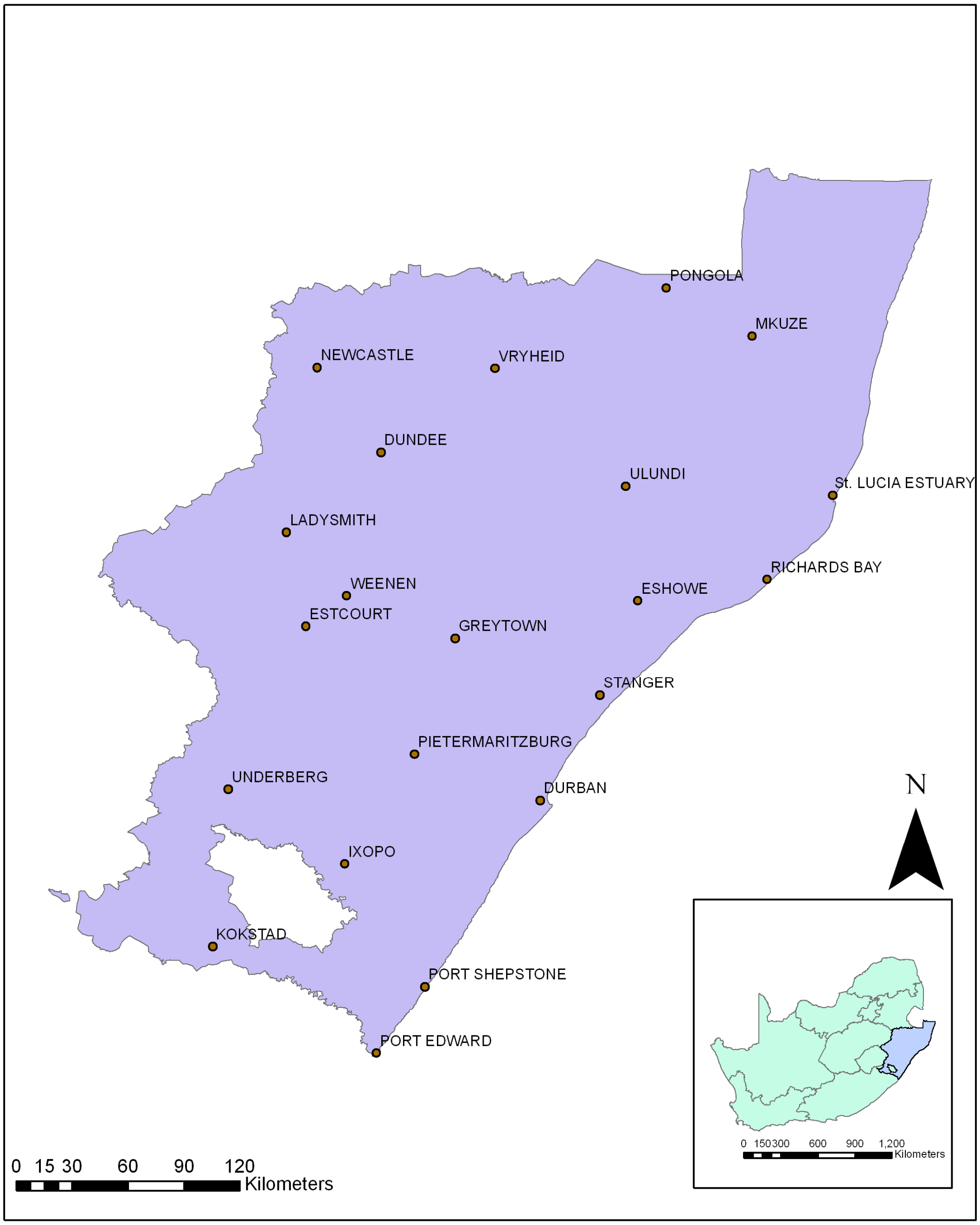

Figure 1.1 The Study Area: KwaZulu-Natal

1.6 Distribution of Oribi in KwaZulu-Natal

In KwaZulu-Natal, Oribi (*Ourebia ourebi* (Zimmerman, 1783)) occur in conservation areas and on privately owned land (Everett, 1991). Marchant (2000) estimates the oribi population to be in the vicinity of +\- 2000 individuals on privately owned land and +\-600 individuals in conservation areas throughout KwaZulu-Natal (*Figure* 1.2). The figures mentioned above were corroborated by the OWG (Resouw and Marchant, Per. Com, 2007). These figures represent the current oribi population statistics available and sadly represent the last remnant of an endangered species. In 1981 a random postal questionnaire survey of antelope numbers on private land in KZN was conducted. The results showed that oribi had disappeared from 23% of the farms where they had previously occurred, which in addition to the now fragmented distribution of oribi due to the considerable increase in land-use such as afforestation (Coverdale *et al*, 2006), was cause for concern. A follow-up survey in 1998 by Ezemvelo KZN Wildlife (EKZNW) to assess the status of oribi on the same 86 farms involved in the 1981 survey provided more alarming results. On 31% of the farms that had oribi in 1981 oribi numbers had declined, and on 25% the oribi have become extinct. The follow-up survey showed an overall downward trend in oribi numbers on private land (*Table* 1.1), and the results suggested that this antelope could now be one of South Africa's most endangered species (Marchant, 2000).

Table 1.1 Comparison of the survey results from 1981 and 1998

Population size class	No. of properties		Proportion of properties	
	1981	1998	1981	1998
0 (Extinct)	20	13	24	25
1-9	45	25	54	49
10-19	9	6	11	12
20-29	6	2	7	4
30-39	2	0	3	0
40-49	0	0	0	0
50-99	0	1	0	2
100+ (150)	1	9	1	0
Present	3	2	-	4
Unsure if present	-	2	-	4
Total	86	51	100	100

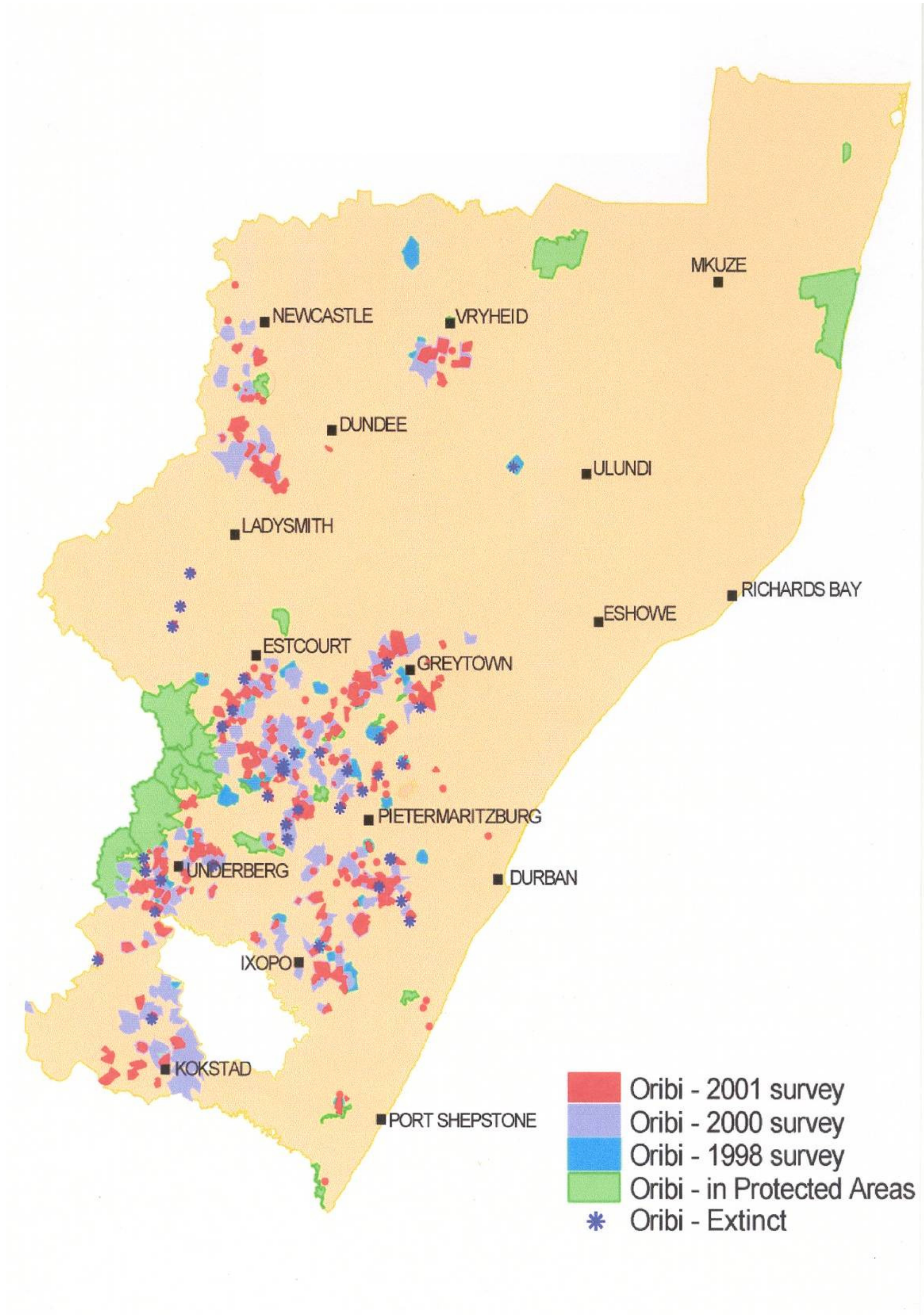

Figure 1.2 Distribution of oribi in KwaZulu-Natal (Marchant and Rushworth, unpublished).

Chapter Two
Literature Review

2.1 Introduction

The plethora of literature on the declining numbers of oribi in KwaZulu-Natal is primarily centered on the behavioral ecology and ecological status of the oribi. None of the oribi-related studies have incorporated GIS as an analysis technique and it is for this reason that there is a dearth of literature on oribi habitat suitability analysis using GIS. The literature review for this report will therefore concentrate on habitat evaluation case studies of species other than oribi, and other cases where multi-criteria evaluation (MCE) was used, thereby gaining practical insight from other studies. Within the literature review, literature associated with each objective identified in Chapter 1 section 1.3.2 will be examined. Following on from this, the possible inconsistencies in the methodologies and associated results obtained from relevant literature will be examined with a view to complementing the theoretical knowledge through subsequent findings.

2.2 GIS in Natural Resource Management

In recent years the drastic improvements in modeling capabilities of geographic information systems has propagated a seemingly endless growth of GIS use in the applied environmental fields. This is particularly evident in the natural resource management sphere as will be shown in the following section with reference to methods pertaining to habitat evaluation.

Geographic information systems have long been seen as species and land use management tools. Early GIS models for land use planning provided multiple uses for forest lands concurrent with timber management facilities (Johnston, 1987). Such techniques have become synonymous with contemporary habitat and species conservation and continue to form the analytical platform on which informed management decisions can be justified (Carver, 1991; Eastman, 1997).

The discrete goals and objectives of conservation planning and management initiatives are equally well suited to the capability of current GIS and Remote Sensing platforms to integrate multiple data types for decision making. Species mapping performs several key functions in the conservation process. Maps depicting the distribution of patterns of individual species are a key tool for making informed judgments about the conservation status of individual species and for identifying geographic gaps in the available conservation datasets (Miller *et al.,*1994). Pena & Bonnet, (2003) recommend that, by combining the spatial representations of species distribution patterns and Multi Criteria Evaluation techniques, critical areas for biodiversity conservation can be logically identified from an analysis of the identified species' habitat patterns and numerical algorithms (Pena & Bonnet, 2003). The following section will offer a short overview of the part Multi-Criteria Evaluation plays in Multi Criteria Decision Analysis (MCDA) situations.

2.3 Multi-Criteria Evaluation

Multi-criteria evaluation (MCE) techniques utilize numerical algorithms that define the suitability of a particular solution on the basis of the input criteria and weights together with some mathematical or logical means of determining trade-offs when conflicts arise (Heydon *et al*., 2003 as cited in Phukon *et al*., 2004). Since the early nineties the integration of multi-criteria decision making (MCDM) models with GIS evolved significantly with Carver's (1991) search for nuclear reactor sites and Hall & Wang's (1992) land use suitability ratings for wetland rice and soybean land allocation. A valuable study was that of Davidson, Theocharopoulous & Bloksma (1994) in which they developed a land resource information system that could relate the incidence of soil erosion to slope, soil order and surface texture. Their approach reflected the popularity of a class based view of the world in that the division of land into suitability classes is seen as more important than the detection of gradual change. Eastman *et al.,* (1995) showed that land assessments characterized by multi-choice alternatives and factors can therefore be enhanced significantly by effective integration of Multi-Criteria Decision Analysis (MCDA) with GIS. Within the concept boundaries of MCE a criterion is a rule to test the desirability of alternative decisions.

The alternatives are all made in an environmental context and therefore involve factors outside the control of the decision maker (e.g. topographical attributes) In the case of

Boolean criteria, sometimes referred to as constraints, the solution usually lies in the union (logical OR) or intersection (logical AND) of conditions (Breytenbach, 2006). However, for continuous factors, a weighted linear combination (Voogd, 1983) is a common technique. Establishing factor weights is the most complicated aspect, for which the most commonly used technique is the pair-wise comparison matrix. Such techniques will be reviewed in the literature relating to the Analytical Hierarchal Processes (AHP) in section 2.3.1.

In a study completed by Pena & Bonnet (2003), several environmental criteria were evaluated to ascertain the suitable habitat extent of two *Euphorbia* species of the Sierra de Aitana region in South Eastern Spain. Pena & Bonnet's plant distribution analysis was conducted by means of MCE association of environmental parameters using GIS (ArcInfo 8.1) with presence/absence and plant density data (Pena & Bonnet, 2003). In a similar study completed by Store and Kangas (2001) the authors encompassed the use of multi-criteria evaluation and expert knowledge in forest management and conservation of an old-forest polypore species, *Skeletocutis odora.* The method relied on the combined use of empirical evaluation models and models based on expert knowledge in a GIS environment (Store and Kangas, 2001).

Michelmore (1994) developed a spatial model to predict elephant distribution and numbers in central African countries where field data was scarce or non-existent. The field survey was conducted in the rainforests of the equatorial regions of Africa. The forests comprise some one third of the range of the African elephant and can harbour and protect hundreds of thousands of elephants (Michelmore, 1994). The methodology involved estimating elephant numbers in forests where they are seldom seen by determining densities from dung-piles. Using multivariate analysis, the proximity of human disturbance was found to be the critical factor influencing the density and distribution of elephants within the forests of Gabon. Elephant densities were found to increase with distance from roads and major rivers where human habitation was concentrated.

Store and Kangas, (2001) supported the notion that a GIS platform provides the ideal technical tools for modeling and connecting (standardizing, weighting, and combining) the habitat needs of an endangered species. The advantages of the methods are made evident when connecting a possibility to consider the habitat factors on different scales, to combine habitat suitability evaluations for several other species, to weight different species in different ways and to integrate empirical models and expert knowledge (Store and Kangas, 2001). The need to structure the environmental factors within the problem in a manageable, hierarchical fashion becomes apparent. Saaty's (1980 and 1994) Analytical Hierarchy Process (AHP) is one such approach where criteria are arranged in a hierarchical structure with the aid of user input. Literature pertaining to Saaty's approach will be reviewed in the following section with reference to the environmental factors indicative of suitable oribi habitat.

2.3.1 The Analytical Hierarchy Process in Multi Criteria Evaluation

The AHP is a multi criteria decision making (MCDM) development that emerged as a promising technique for the development of weights (Eastman *et al.,* 1995). Post decomposition, the AHP process requires the assessment of pair-wise comparisons and uses a linear 9-point continuous scale to tally the criteria. It is fundamentally held within the context of these pair-wise comparisons that Saaty's comparison matrices are considered effective ways of extracting qualitative information for real world MCDM problems. Saaty uses the Eigenvalue theory to synthesize the priorities. The Eigenvalue Concept, which is a least squares problem in AHP, falls outside the scope of this project but for further reading please refer to Saaty's (1994) work. In-depth theoretical background of the AHP can be found in voluminous literature (e.g., Yager 1979, Saaty 1980, 1987a, b, 1990, Saaty and Kearns 1985, Zahedi 1986, Weiss 1987, Saaty 1994) and is not discussed here.

AHP is notably more time efficient when utilized in a GIS environment. The computing power of today's GIS platforms improves the user's ability to link AHP weighting with spatial representations and therefore digest and analyse far greater amounts of spatial data. The primary popularity of this method can be found in the fact that users with a non-mathematical background are provided with steps to handle complex criteria through forming a hierarchical structure and performing pair-wise comparisons. Banai (1993) used this technique in combination with GIS. In his study Banai (1993) searched for landfill areas guided by the relative weights of the suitability factors obtained in the AHP. The fuzzy set theory by Zahedi (1986) was also utilized in assigning gradients with the union of various polygon buffers generated by GIS overlay operations. Phukon *et al.,* (2004) utilised MCE and AHP techniques in a GIS environment. In their study, ground water resources were identified using similar techniques to those used in the Oribi habitat suitability analysis. The city of Guwahati, with a total municipal area of more than 313 sq. km, has witnessed a rapid growth in population, particularly during the last one and half decades. The population jumped from 123,783 in 1971 to 577,791 in 1991 and as per census 2001 (Phukon *et al.,* 2004). As a result, there was tremendous pressure on natural resources like groundwater. The rapid growth of built up areas and filling up of natural channel ways have adversely affected recharge of the ground water regime. MCE and GIS were used to identify the groundwater potential zones of the city area, taking into account the geological and anthropogenic factors. Using AHP (Saaty, 1980), a paired comparison matrix was prepared for the five criteria (geomorphology, slope, soil, geology and land use) for Guwahati city. The computed values show an acceptable level of consistencies. The consistency ratio (CR) for all the five thematic layers was found to be 0.013, while for the individual criterion the CR values were: geomorphology (0.0039), soil (0.00528), slope (0.0176), geology (0) and land use (0.0053), which were within the acceptable limit of 0.10. The weights were fed into the SPANS 7.2 for multi-criteria analysis to determine the groundwater potential zones for the city (Phukon *et al.,* 2004).

In each of the Multi-Criteria Evaluation cases reviewed, a concerted level of expert knowledge was utilized to create informed judgments relating to the study objectives at hand. The level of robustness of the above mentioned cases is determined by the comprehensive review and subsequent application of relevant literature in the modeling process. In this context it is essential that we review the relevant literature relating to the habitat requirements of the oribi antelope in an effort to secure informed judgments.

2.4 Oribi Research

Aspects of oribi ecology have been undertaken by various researchers. Viljoen (1982) produced a detailed study on the behavioural ecology of oribi in the former South Eastern Transvaal. Reilly (1989) studied their general ecology in the Golden Gate National Park. Aspects such as limiting factors, population ecology, habitat preferences, carrying capacities and management are adequately covered by Mentis (1978); Oliver, Short and Hanks (1978); Rowe-Rowe (1982a); (1982b); (1983); Rowe-Rowe and Scotcher (1986); and Marchant (1991). Everett (1991) evaluated the status and ecology of populations in KwaZulu Natal; Marchant (2000) subsequently compared Howard and Marchant (1984) population numbers in Nature Reserves and private land to a 1998 oribi population census (KZNNCS, 1998). In the following section, the habitat requirements and behaviour of the oribi will be explored with specific reference to the oribi habitat suitability model.

2.5 Habitat Requirements and Behaviour

The description of the physical and biological properties of an animal's preferred habitat can be referred to as habitat use (Everett, 1991). The knowledge obtained by such studies is integral to the successful conservation of habitat, and is a precondition for the conservation of target species (Everett, 1991). The knowledge acquired also allows man to manipulate the key habitat factors essential for the animals' survival (Howard, 1983: Everett, 1991) and is a prerequisite for the prediction of successful reintroduction of a species (Pienaar, 1974: Everett, 1991).

Oribi are highly specialized antelopes and are seasonal breeders, calving from October to December. Oribi are water-independent and tend to favour moist grassland on gently undulating terrain with usually less than 10 º slopes (Mentis, 1978; Oliver *et al*, 1978; Rowe-Rowe, 1982 a; 1982 b; 1983; Rowe-Rowe and Scotcher, 1986; Marchant, 1991; Everett, 1991; Marchant and Rushworth, 2004). The terrain specific to the oribi requires actively growing short grass for food adjacent to long grass which is required to provide cover from the elements and predators (Viljoen, 1982; Reilly, 1989; Everett, 1991; Marchant, 1991) as well as shelter for the young which are left to "lie out" for the first 8 to 10 weeks (Mentis, 1978; Oliver *et al*, 1978; Rowe-Rowe, 1982 a; 1982 b; 1983; Rowe-Rowe and Scotcher, 1986; Marchant, 1991; Everett, 1991; Marchant and Rushworth, 2004). In KZN, lowlands appear to be avoided (Everett, 1991). Oribi seldom use agricultural lands or pastures such as oats and rye grass as a source of supplementary winter food as do common reedbuck (Everett, 1991; Marchant, 1991). Recently, however, there have been a few isolated records of them feeding on young sugarcane, and on rye grass under centre pivots (OWG, 2004). Oribi do favour both natural and planted (Eragrostis, K11, etc) hayfields (OWG, 2004).

Oribi are highly selective feeders, selecting not only for short grass, but also for certain species of grass, and certain parts of those grasses. In KZN and in Mpumalanga, oribi prefer natural grasslands dominated by *Themeda triandra* (red grass), a grass species considered to be one of the most valuable veld species and an indicator of good veld. Most oribi occur in the harsher climates of KZN, such as the mistbelt and highland sourveld areas, where winters are severe and the food quantity and quality is at its' lowest. (Everett, 1991)

It is typical that small-bodied antelopes, which feed very selectively on highly nutritious food, are widely dispersed as their preferred food is generally not abundant. Oribi thus occur in pairs or small family groups (Reilly, 1989; Everett,1991). Oribi are territorial and their home range size varies considerably between 28 ha in the Transvaal (Viljoen, 1975), and 60 ha in Natal (Everett, 1991), with several other estimates falling within this range (Oliver *et al.,* 1978, Spinage, 1986 and Reilly, 1989). Oliver *et al.,* (1978), found the mean home range size to be 49.2 ha within the Drakensberg area. Within East Africa, Spinage (1986) estimated home ranges to be 25 ha in extent, whilst Reilly (1989) found the mean size to be 23.1 ha within the Golden Gate National Park. They defend their territories against other oribi, as well as chasing the male calves out when these calves reach one year of age. Natural densities range from one oribi per 30 ha to one per 9 ha, depending on the amount of suitable habitat, the quality of food and the quality of management (Everett, 1991; Marchant, 1991). In addition, territorial behaviour also influences the density of oribi, and in good habitat territory sizes are small, allowing for a greater density of oribi in that area. Oribi in KZN therefore occur naturally in low numbers. The effects of habitat destruction and fragmentation, veld mismanagement, or poaching with dogs thus could be quite devastating. Apart from trying to halt these destructive processes, the only other option is to boost the stocking rates of oribi in the remaining suitable habitat. Landowners applying a sound burning, cattle grazing and mowing programme can boost oribi numbers on their properties (Everett, 1991; Marchant, 1991).

A summary of the habitat requirements of oribi as reviewed in the literature are described below (After Coverdale *et al*, 2006):

- Aspect of slope: Rowe-Rowe (1983) and Everett (1991) found that oribi favour the north and east facing slopes and show a negative selection towards the south and southeastern facing slopes.
- Degree of slope: Oliver *et al.,* (1978), found that 90% of the oribi within the Highmoor Nature Reserve occur on slopes less than 15°. Within the Giants Castle Nature Reserve, oribi favour gentle slopes (5° or less) and gentle undulating plateaus and ridge tops with a slope of less than 10° (Rowe-Rowe, 1983). Within the Transvaal, Viljoen (1982), found oribi to prefer plateaus and spurs of between 1° and 20°.
- Topography: Oribi tend to avoid lowland areas, preferring ridge terraces and avoiding flat land and steep slopes (Everett, 1991). Within the Serengeti, Mduma and Sinclair (1994) found that oribi prefer rocky outcrops, suggesting that it provides hiding places during the dry season when the grass is short or alternatively providing green grass when other areas are dry.
- Vegetation: Oribi show a preference for open natural grassland dominated by *Themeda triandra*, veld hayfields and planted hayfields. Oribi avoid, however, planted pastures, croplands and plantations (Everett, 1991; Shackleton and Walker, 1995). A small group of oribi (five individuals) were observed within a vlei adjacent to two *Eucalyptus* plantations within the Hlatikulu region of Kwazulu-Natal (pers. obs.), this despite the relative proximity to vast areas of open grassland. Oribi also have a high tendency to frequent recently burnt veld because of its high nutritional status (Oliver *et al.,* 1978; Everett *et al.,* 1991).

2.6 Habitat Fragmentation

Habitat reduction and fragmentation at a variety of spatial scales has been widely acknowledged as the primary cause of the decline of many species worldwide (Ehrlich and Ehrlich 1987, Lovejoy *et al.,* 1986, Harris 1984). Authors who corroborate with the negative effect habitat fragmentation has on oribi population include: Mentis, (1978);

Oliver, Short and Hanks, (1978); Rowe-Rowe, (1982a); (1982b); (1983); Rowe-Rowe and Scotcher, (1986); Marchant, (1991); Everett, (1991); Marchant and Rushworth, (2004). Habitat fragmentation generally leads to smaller and more isolated animal populations. Smaller populations are then more vulnerable to local extinction, due to stochastic events (Shaffer 1987, Gilpin and Soule 1986), and the species are more susceptible to the negative effects of inbreeding depression. To reduce the isolation of habitat fragments, many conservation biologists (e.g. Noss 1987, Noss and Harris 1986, Craighead., 1994, Craighead and Vyse 1996, Paetkau *et al*., 1997) have recommended maintaining landscape "connectivity" viz: preserving habitat for movement of species between remaining fragments. In this context we will now briefly look at methodologies available to create connectivity between the fragmented habitat using wildlife corridors.

2.7 Habitat Corridor Delineation

Wildlife corridors are valuable conservation tools for maintaining connected and viable populations of some species, especially in areas where little functional habitat remains (Schultz 1998, Schultz and Crone 2005). Corridors have been utilised in a number of instances. In a recent study completed by Shepherd and Whittington (2006), a historically recorded wolf corridor was restored after a golf course had bisected the wolves' core nodes of habitat. A reconfiguration of the boundary fences around the golf course made allowances for wolf movement between two integral habitat core areas. In another case Walker and Craighead (1997) identified wildlife corridors in the US Northern Rockies. This was completed through an analysis of three focal species: elk, grizzly bears and mountain lions. The initial findings revealed the predicted corridors of each species overlapped greatly (Walker & Craighead 1997). Therefore, in subsequent phases of analysis, only the grizzly bear - whose habitat requirements and sensitivity to regional-scale disturbance make it an ideal umbrella species - was used as a predictor (Walker & Craighead 1997; Carroll *et al.,* 2002). The authors identified the potential connective corridors by normalising environmental input variables and combining them through a linear equation in a GIS environment. The resultant cost surface coverage was then used to identify core habitat zones and subsequent linkages with the use of the ArcMap least cost path module (Walker & Craighead 1997). The critical aspect of corridor identification in this study would thus involve the evaluation of potential oribi habitat linkage zones based on Multi-Criteria Evaluation and cost distance coverage.

2.8 Lessons Learnt from the Literature Review

The following section firstly highlights the possible inconsistencies in the methodology of the reviewed literature, and then identifies strengths which may contribute to the theoretical knowledge needed to complete the objectives established in Chapter One of this project.

2.8.1 Mapping Natural Features

In reviewing the plethora of literature, a common inconsistency was identified in the methodologies utilised to produce the necessary spatial representations of reality. The inherent inconsistency stems from mapping natural boundaries, such as species habitats, to an unfeasible degree of precision. Even with advances in GPS and other positional technologies, man-made structural features will still be mapped with a higher level of user confidence than boundaries of natural features (Miller, 1994). The boundaries of structural features are discrete and they usually can be precisely located on a map using object and feature pictorial identifiers. Alternatively, the boundaries of most natural features (i.e. oribi habitat distribution) are not usually definable in the same way. The movements of animals are not precisely predictable from one moment to the next. The boundaries of habitats change regularly due to the effects of climate, succession, disturbance, etc. In addition to the potential of blurring feature boundaries, any single map represents only one of the many cartographic views of a data set (Monmonier, 1993). It is therefore important to access the realism, accuracy and the effectiveness of the depiction of important habitat features whilst carefully considering the design of suitability maps. In addition, the definitions, quantifications and variability of the elements used to map key habitat features need to be carefully validated (Miller, 1994). In the context of this study, specific mention must be given to data scale limitations and to the inherent inaccuracy as map scales decrease (Goodchild, 1980). Similarly, on a small map scale that covers a broad area, patterns of species distribution are generalised to display the species range across the entire region being shown by the map. As did Michelmore's (1994) regional elephant study in central Africa, this study of oribi habitat will take cognisance of scale effectiveness issues when identifying possible suitable habitat.

2.8.2 Oribi Research

The literature pertaining to oribi ecology reviewed in this study was limited to work completed at a localised spatial scale. Viljoen (1982) produced a detailed study on the behavioural ecology of oribi in the former South Eastern Transvaal whilst Reilly (1989) studied their general ecology in the Golden Gate National Park. Aspects such as limiting factors, population ecology, habitat preferences, carrying capacities and management are adequately covered by Mentis (1978); Oliver, Short and Hanks (1978); Rowe-Rowe (1982a); (1982b); (1983); Rowe-Rowe and Scotcher (1986); and Marchant (1991), Everett (1991) evaluated the status and ecology of populations in KwaZulu Natal; Marchant (2000) subsequently compared Howard and Marchant's (1981) population numbers in Nature Reserves and private land to a 1998 oribi population census (KZNNCS, 1998). However, many ecologically centred oribi studies can be criticised because of the paucity of habitat evaluation information at a regional scale. No studies have examined oribi habitat corridors or habitat linkages using GIS platforms.

2.8.3 Multi Criteria Evaluation

When considering the reviewed literature pertaining to Multi-Criteria Evaluation techniques, one major advantage was identified. Multi Criteria Evaluation provides the basis to consider a broad number of data, relations and objectives which are generally present in specific problems; ultimately this enables the issue at hand to be studied in a multidimensional fashion (Heydon *et. al*., 2003). The use of multidimensional techniques is not without limitations (Wegner, 2007), and within the context of this study it is necessary to consider these.

The methodological limitations of Multi criteria evaluation are that results will be reliant on

- the available data
- structured information
- the chosen aggregation method
- the decision-makers' preferences

(After, Wagner, 2007)

2.8.4 Analytical Hierarchical Process (AHP)

In the context of this study, the reviewed literature revealed one strength of the AHP process, viz. that it does allow for inconsistent and intransitive relationships while, at the same time, providing a measure of the inconsistency (Saaty, 1994). This strength of AHP has been criticised by multi-attribute utility theory (MAUT) and expected utility theory researchers because it does not conform to their axioms, one of which is the transitivity of preferences (Zografos and Giannouli 2001). Another AHP drawback is that pair-wise comparisons are lengthy and time consuming processes when considering a multitude of criteria. For instance, if there are n objects to be analysed, there would be a $n(n-1)/2$ complete set of pair-wise comparisons to be made.

Expected utility theory is grounded on the axiom of transitivity, that is, if A is preferred to B, and B is preferred to C, then A is preferred to C (or if A is three times more preferable than B and B is twice as preferable than C, then A is six times more preferable as C) (see Appendix A).

Another strength of the AHP method is the objective calculation of the internal uncertainty which is measured through an index constructed to calculate the level of consistency in the pair-wise comparisons (Zografos & Giannouli, 2001). This is determined through Saaty's (1980) development of the *Consistency Ratio* (CR), which involved the maximum right Eigenvalue (Phukon *et al.,* 2004).

Authors Zografos and Giannouli (2001) listed the advantages of using this method as follows:

1. Provides a structured way of making judgment
2. Provides a uniform level of reliability of the results
3. Provides the ability to justify the outcome
4. Provides a causal thinking
5. Combines qualitative and quantitative criteria
6. Takes into account the research literature but also allows "compromising solutions", when unavoidable
7. Allows for sensitivity analysis for the following:

a. Classification (weighting) of dimensions in order of importance

b. Classification (weighting) of factors in order of importance

c. Development of the Analytic Hierarchy Process evaluation model

d. Assessment of alternatives' potential

e. Multi-criteria analysis realisation

f. Discussion of findings and sensitivity analysis

(After, Zografos & Giannouli, 2001)

2.8.5 Habitat Corridor Delineation

On reviewing the literature pertaining to wildlife corridors, certain methodological inconsistencies were identified with specific similarities relating to this study.

The benefits of corridors are often species specific (Beier and Noss 1998, Haddad *et al.,* 2003), and corridors can also affect important ecological interactions (Tewksbury *et al.,* 2002). Shepherd *et al.,* (2006) define a corridor as a narrow landscape element used by wildlife to travel or migrate from one habitat patch to another (Beier and Noss 1998, Soule and Gilpin 1991). However, many corridor studies have been criticised because they lack corroborative movement data (Rosenberg *et al.,* 1997). In addition, many corridor studies fail to demonstrate how animal movements change with the presence and absence of corridors (Rosenberg *et al.,* 1997), nor do they compare the frequency of movements inside vs. outside the corridors (Beier and Noss 1998). Finally, few studies have examined the effect of corridors on animals that occur at low population density, such as the oribi.

2.9 Conclusion

The literature has shown the extent to which habitats and corridors have been mapped and evaluated with specific reference to techniques such as MCE and AHP. The inconsistencies identified in the literature review are primarily the ones motivating this study.

This chapter has outlined some of the major themes for the study. Chapter Three will outline the techniques used in the study.

Chapter Three

Methods

3.1 Introduction

This chapter provides an overview of the data collection and analysis methods used to determine the habitat suitability index, the cost distance algorithms and suitable habitat corridor identification for the oribi in KwaZulu-Natal. The chapter highlights the general methods used. The sampling strategy, field data collection procedures, materials used, preparation of surface maps and an overview of the spatial modeling techniques (Figure 3.0) are highlighted in this chapter.

3.1.1 Background

The broad scale use of Geographic Information Systems and Remote Sensing in wildlife habitat modeling has increased exponentially over the past two decades (Skidmore, 2002). The increase of usage can largely be attributed to the rise in hardware accessibility and processing power witnessed over the past twenty years. GIS are powerful and sophisticated tools for displaying and analysing spatial relationships between geographic phenomena in the form of vectors and images (Skidmore, 2004). GIS are useful tools in natural resource management studies because of their ability to perform analysis of spatial overlay with ease over regional to provincial scale areas. The basis of the project process is the spatial overlay. The results of the spatial overlay were analysed through a standard Multi-Criteria Evaluation technique using a Univariate and Multi-Variant statistical analysis and Saaty's (1980) Analytical Hierarchy Principle. The resultant habitat suitability model was then utilised in Cost Distance analysis of which a collation of the results was used to identify oribi Conservation Area Networks and suitable habitat corridors for oribi in KwaZulu-Natal.

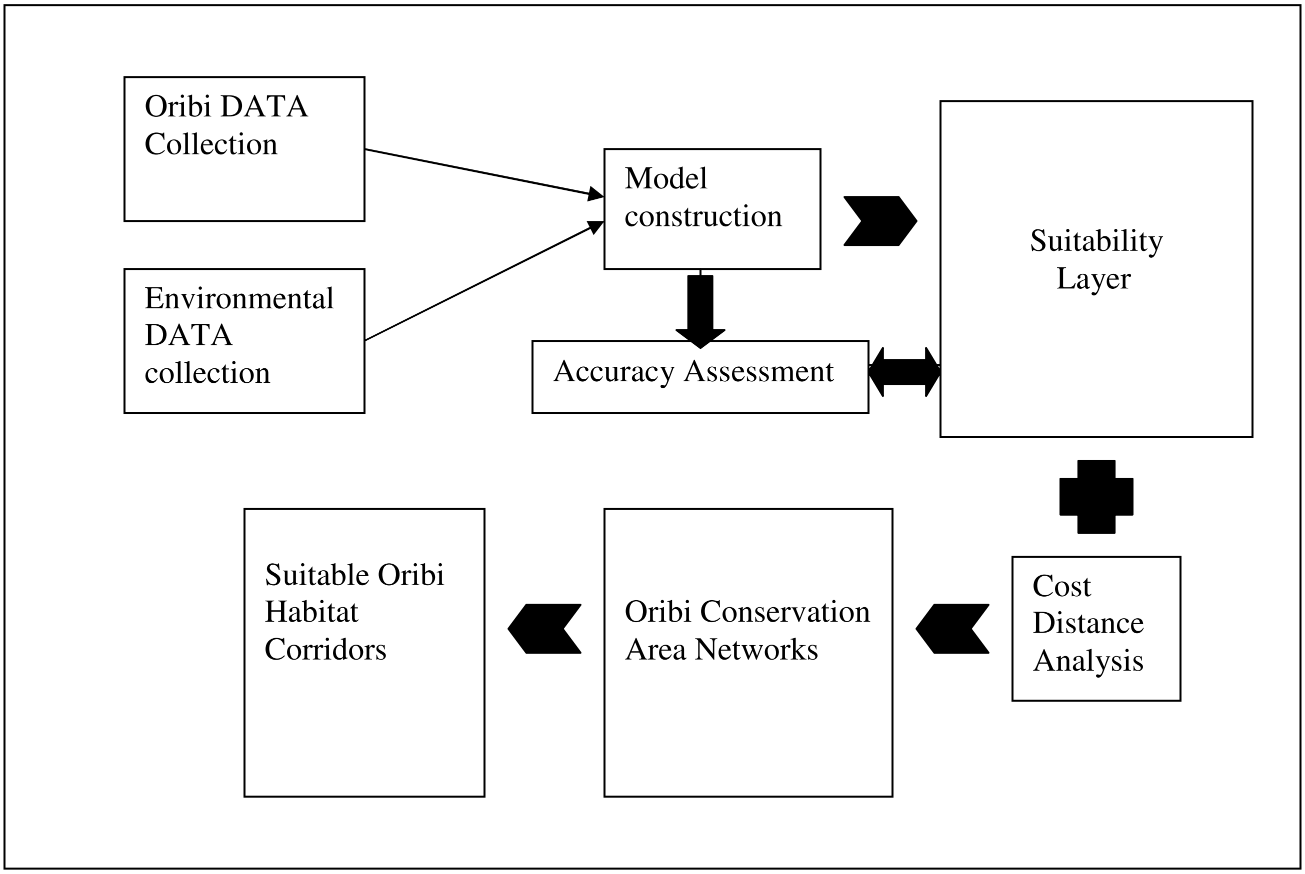

Figure 3.0: Simplified flow diagram of the overarching methods used (After ***Figure 3.3***)

3.2 Multi-Criteria Evaluation

The methods used in this project follow a standardised Multi-Criteria Evaluation (MCE). Oribi distribution analysis was conducted by means of MCE association of environmental parameters using GIS (ArcGIS 9.2) with Oribi positional data. MCE techniques are numerical algorithms that define the suitability of a particular solution on the basis of the input criteria and weights, together with some mathematical or logical means of determining trade-offs (Peña & Bonet, 2003). In this technique, 'weight' is assigned to the data layers to reflect their relative importance. Such MCE's take into account a range of environmental and anthropocentric variables to produce an end result. In this case, all the criteria were considered restrictions and the result was its intersection suitability index. With this method we are able to create ranked maps by means of a reclassification of the characteristics of each thematic variable. It is important to understand the control of these variables on the distribution of oribi in any area for natural resource conservation and habitat management. As such, to arrive at a clear picture of the situation, the controlling factors have to be treated and integrated and given weight that is specific to oribi habitat importance. The end result is in a map format and clearly defines areas that are of interest to the relevant authorities. In the case of this project, the final map gives an indication of the land remaining in KwaZulu-Natal that is suitable for oribi habitation.

3.3 Field Data Collection

The field data used in the model was collected in 2001 through a random postal questionnaire survey of antelope numbers on private land in KZN. Ezemvelo KZN Wildlife (EKZNW) initiated the survey to assess the status of oribi on 86 farms. A short questionnaire was distributed to landowners. This questionnaire recorded information such as: contact details, property details, total oribi population, population stability, habitat type, main farming activity, and a general inquiry on the burning regime. These same 86 farms were investigated previously by Howard and Marchant in 1981 and then again by Marchant in 1998. The data for the EKZNW reserves were obtained from the Regional Ecologists and Officer-in-Charge of the relevant reserves, and from the Natal Parks Board (1982/83, 83/84, 85/86), Conservation Division Yearbooks, and the Natal Parks Board (89/90) Yearbook (Marchant, 2000). The oribi population data, consisting of Global Positioning System (GPS) coordinates and population numbers, was a culmination of the Howard and Marchant (1984) and the Marchant (2000) postal surveys. This project has used the GPS point data from the 2001 census consisting of 32 sampling points across KwaZulu-Natal (Figures 3.1 & 3.2)

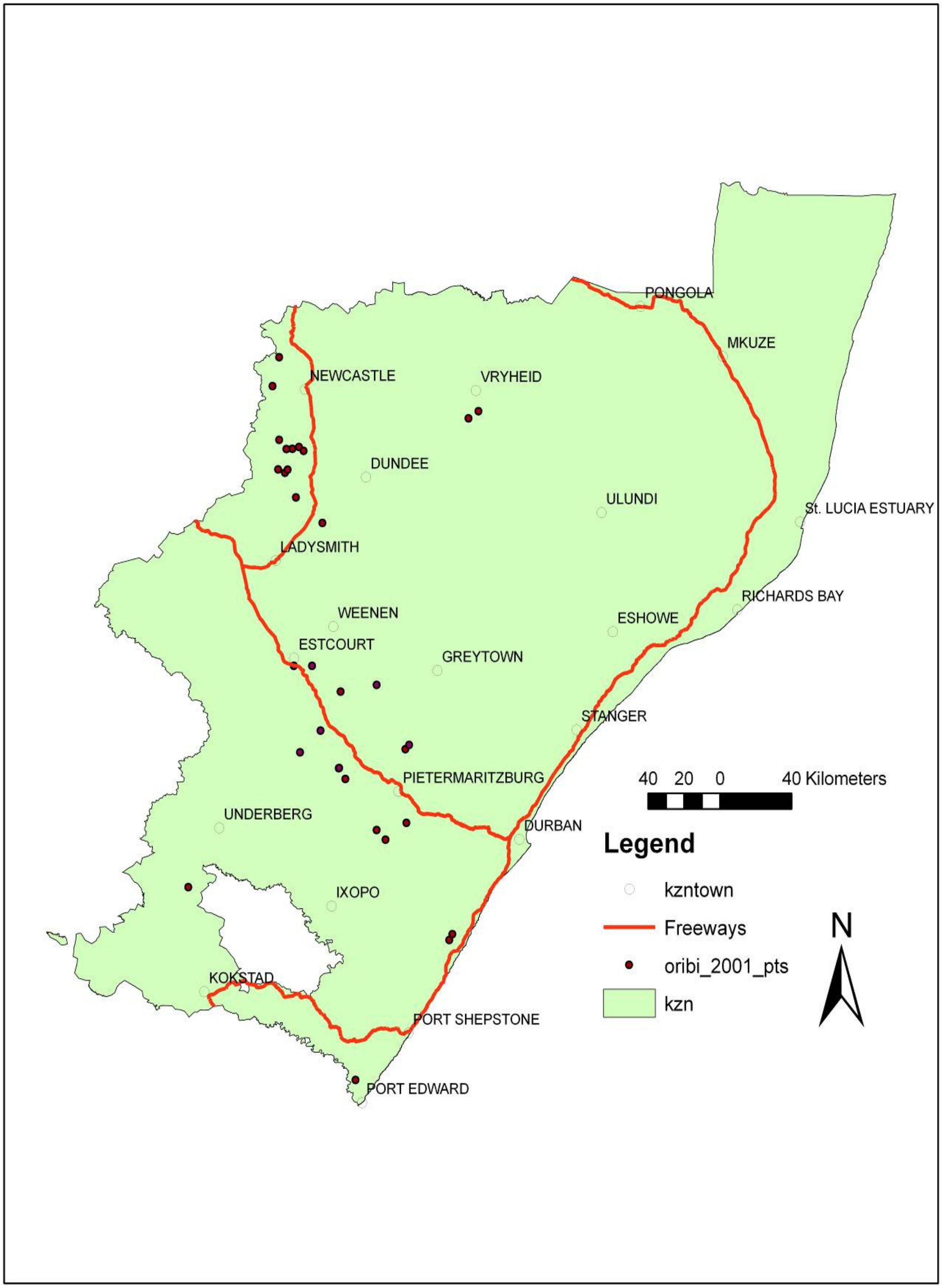

Figure 3.1 Study Site showing GPS Point data from 2001 census, covering the Province of KwaZulu-Natal

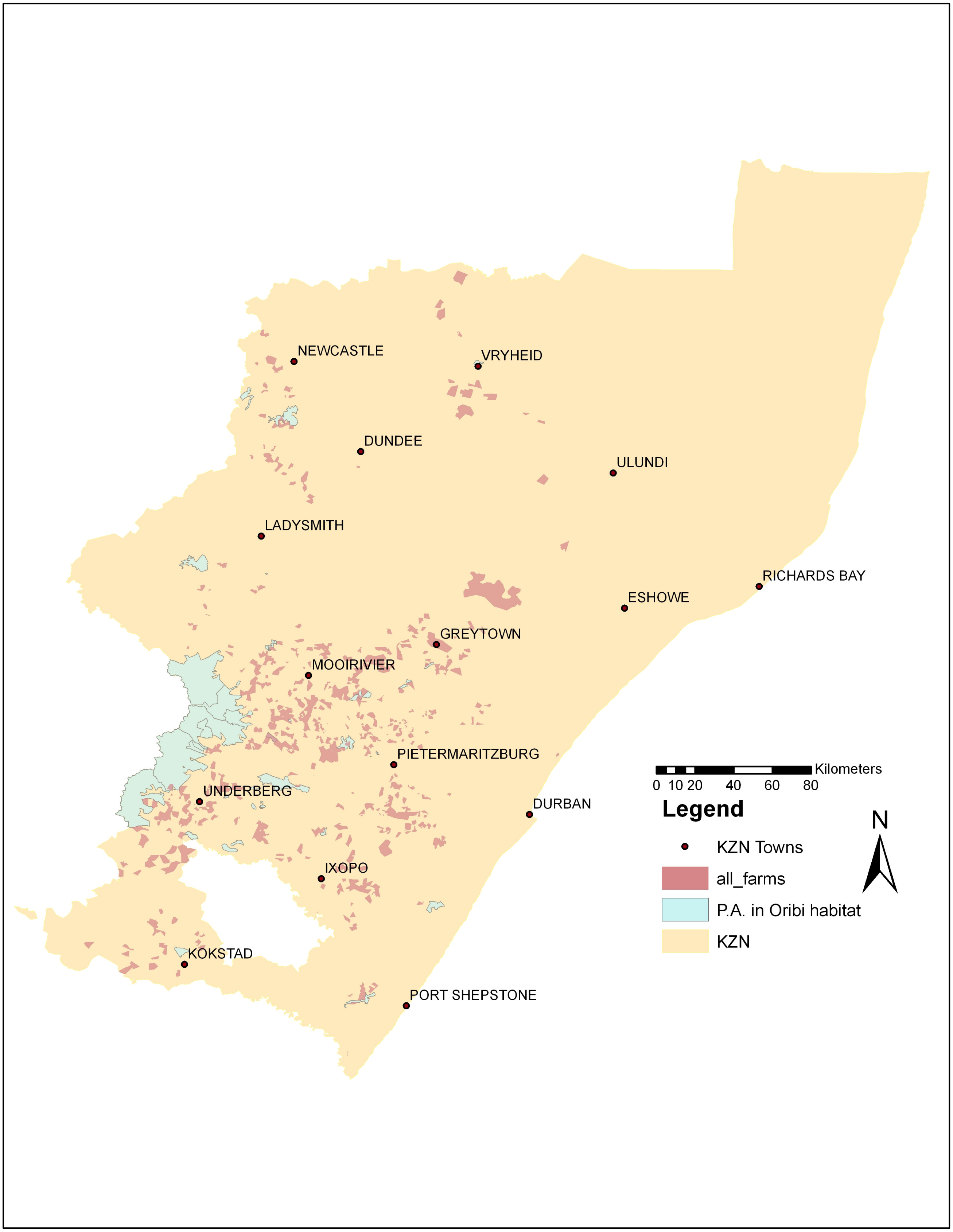

Figure 3.2 Study site showing the land parcels with oribi census returns

3.3.1 Oribi Population Data Collation

In 2004 the oribi specific Geodatabase (ESRI propriety database structure) was created for EKZNW. All oribi census returns from 1998 to 2005 were recorded including the individual land parcel surveyor general cadastral information. The information provided by the census returns on the land parcels corresponded to the cadastral shapefile layer as provided by the Surveyor General. This key piece of information allowed EKZNW to build the oribi Geodatabase based on the geographic position of the land parcels with oribi census returns. The total number of land parcels was 456 excluding the 16 EKZNW Protected Area land parcels. The Geodatabase is housed at the Queen Elizabeth Park headquarters of EKZNW and holds all records relative to oribi census returns in KwaZulu-Natal from 1998 to 2005.

3.4 Software

The following software packages were used:

• Data entry & calculations	EXCEL SPREADSHEETS
• GIS processing	ARCVIEW/ ARCGIS
• Statistical analysis	STATISTICA
• Word processing	MS WORD

3.5 GIS Data Layers

The data layers used in the analysis were; Slope, Aspect, Land Cover, BioResource Groups, KwaZulu-Natal Vegetation, Mean Annual Precipitation, Altitude and Annual Average Temperature (Table 3.1). The variables were selected through a literary review process of the available habitat requirement studies relevant to the oribi. These findings were corroborated by habitat requirement studies completed by Mduma and Sinclair (1994), Plewman and Dooley (1995), Everett (1991) Rowe-Rowe (1983), Oliver *et al.,* (1978) Shackleton and Walker (1995) and Viljoen (1982)

3.5.1 Data Preparation

Table 3.1 Explanatory variables used in this study, together with their definitions

Variable	Definition
ALTITUDE	Continuous variable derived from a DEM, measures height above sea level
SLOPE	Continuous variable derived from a DEM, expressed in degrees, classified into classes
ASPECT	Continuous variable derived from a DEM, expressed in degrees, classified into classes
M.A.P	Continuous variable, expressed in millimetres per year
ANATEMP	Continuous variable, expressed in degrees Celsius
VEG TYPE	Categorical variable, vegetation types
LANDCOVER	Categorical variable, Land cover types
B.R.G	Categorical variable, Bio resource group
Farm Cost distance	Continuous variable derived from the suitability index and distance from oribi farms
Oribi Land Parcels	Continuous variable collected in oribi population census (2001-2005)

3.5.1.1 Oribi Population Data

A vector GIS coincident for the 2001 oribi population numbers was captured and digitized in ArcView 3.3 and recorded in the 2001 oribi census data set. The oribi population size, GPS coordinates, habitat type, burning regime and farmers' details were recorded from the field data collection process (Marchant, 2001).

3.5.1.1.1 Oribi Land Parcels

The corresponding vector GIS coincident for the 2001 up until 2005 oribi census returns was utilised. The data was captured in ArcGIS 9 editor and contains the contact details, property details (i.e. property name, deeds number, magisterial district), oribi census information (i.e. number of oribi, number of groups, males, females and juveniles counted, listed threats to the oribi)

3.5.1.2 Digital Elevation Model

A digital elevation model (DEM) with a resolution of 20m was created through a digitised copy of the South African 1:50 000 topographical map sheets obtained from the Surveyor General's Office. The DEM was used to derive elevation, slope and aspect using the 3D Analysist and Spatial Analysist functions in ArcGIS 9. The aspect was then reclassified into eight classes each representing N, NE, E, SE, S, SW, W and NW. The slope was reclassified into five classes, these were 0^{o}-5^{o}, 5^{o}-10^{o}, 10^{o}-15^{o}, 15^{o}-20^{o} and >20^{o} in line with those used by Everett (1991).

3.5.1.3 Climate

Meteorological data (mean annual precipitation, annual average temperature) were supplied by the KwaZulu-Natal Department of Agriculture, Cedara. The meteorological data sets were continuous variables providing a complete coverage of the KwaZulu-Natal province. Within the Serengeti, Mduma and Sinclair (1994) found such meteorological data indicative of oribi population density.

3.5.1.4 Land Cover

The National Land Cover (NLC) data layer used in the analysis is a medium to large scale classification of land cover in KwaZulu-Natal. The layer was supplied by Ezemvelo KZN Wildlife and jointly coordinated by the Council for Scientific and Industrial Research (CSIR) and Agricultural Research Council (ARC). Refer to Appendix B for further information.

3.5.1.5 BioResource Units

The Bio Resource Units (BRU) (Camp, 1995) layer was supplied by The Department of Agriculture; Cedara. The BRU is a demarcated area of land, throughout which there are recurring patterns of topography, soils, vegetation and climate (Camp,1995). The units were developed for the purpose of regional and farm development planning (Pratt and Gwynne, 1977). The main criteria used in the delineation of the units were primarily climatic factors; rainfall and temperature (Camp, 1995). The BRU were delineated at a scale of 1:50 000 using the South African Topographic Map sheets and would therefore provide an adequate scale of analysis for this project. This thematic layer was reclassified into 23 classes, representing the BRU of KZN.

3.5.1.6 KwaZulu-Natal Vegetation Types

The KwaZulu-Natal vegetation layer was supplied by Ezemvelo KZN Wildlife, and provided a Provincial scale delineation of the vegetation types to an accurate scale of 1:50 000. The vegetation delineation was digitised using the South African Surveyor General 1:10 000 orthophoto series.

3.5.1.7 Cost Distance to Oribi Land Parcels

The cost distance to oribi land parcels was derived using the habitat suitability index map and the oribi land parcels layer. The layer was then classified into two layers, protected areas with suitable oribi habitat and private land with an oribi census record return between 1998 and 2005. The layers were created using the Spatial Analysist: Cost Distance tool in ArcGIS 9.x

3.6 Univariate Data Analysis

Correlation analysis was done to establish the relationship between continuous variables and the oribi population data. Analysis of variance (ANOVA) techniques were used for a set of statistical problems in which one is interested in the effect of one or more non-metric variables on a single dependant variable. An ANOVA is described as a technique to test for differences between the means of two or more groups of subpopulations. The concept of ANOVA is that sample values almost invariably differ but the analysis will identify whether the differences among the samples signify genuine differences, or whether they represent chance variations such as are to be expected among several random samples from the source populations. A one–way ANOVA was used to test if there were any significant differences in oribi population concentrations between different environmental variables. The ANOVA analysis p-value then allowed a ranking of the environmental variables based on the importance and significance to the distribution of oribi.

(refer to *Results* chapter for ANOVA results)

3.7 Multivariate Data Analysis

Many patterns in a real world ecological system are driven by a number of interacting ecological processes that vary in space and time (McGarigal *et al.,* 2000) The interaction and interface of many causal factors makes it possible to simultaneously analyse relationships between the factors (Mutanga, 2000). A forward Stepwise regression was used to investigate the interaction of variables as well as identifying the most important factors explaining the distribution of oribi. An interaction between factors means that the effect of one factor is not independent of the presence of a particular level of the other factor (McGarigal *et al.,* 2000). With the relatively low number of significant correlation coefficients being obtained from the initial correlation analysis, a Forward Stepwise Regression analysis was used to explain the importance of the interaction between the continuous variables and provide a means of weighting these variables for further use in the spatial modeling procedure to follow.

3.8 Multi-Criteria Evaluation Modeling

The univariate and multivariate statistical analysis provided the basis for the modeling procedure. Due to the wide-ranging nature of the non-continuous and continuous environmental variables, a common scale on which an inter-variable comparison could be made statistically was required. This process was made possible with the use of Analytical Hierarchy Principle (AHP) analysis (Saaty, 1980).

3.8.1 Developing Environmental Variable Class Weights

An AHP analysis was completed within the scope of this project to determine the overall weights given to individual variables necessary in the MCE (Refer to Appendix A). The AHP is a multi criteria decision-making technique for the development of weights (Eastman *et al.,* 1995). After decomposition, AHP requires the assessment of pair-wise comparisons and uses a linear 9-point continuous scale to quantify them. Saaty's use of pair-wise comparisons in judgment matrices has become a relatively widely accepted method for extracting quantitative information from day to day multi criteria decision making models (Eastman *et al.,* 1995). To synthesise the priorities, Saaty's method uses the eigenvalue theory which is a modified least squares problem in AHP. For further reading on this concept please refer to Saaty's (2004) latest work as this falls outside the scope of this project. Saaty's use of the eigenvalue theory entails the construction of a decision making matrix by using the relative importance of alternatives in terms of each criterion. To measure the level of internal uncertainty Saaty (1980) proposed the use of an index to evaluate the reasonable level of consistency in the pair-wise comparisons. The consistency ratio (CR) involves the maximum right eigenvalue. The CR is designed in such a way that if CR< 0.10, the ratio indicates a reasonable level of consistency. If the CR> 0.10 there is an unacceptable level of consistency and indicates inconsistent judgments. Using the AHP each environmental variable was ranked against other environmental variables.

Table 3.2 The environmental variables weighted through the AHP

Variable
Mean Annual Precipitation
Mean Annual Temperature
Bio Resource Groups
KZN Vegetation Cover
KZN Landcover
Slope
Aspect

The GIS based MCE that followed required separate weights to be assigned to each variable as a general measure of the variables importance. A pair-wise comparison matrix was created in Excel (MS Office, 2003) and provided the platform for the PHA analysis.

(Refer to Appendix A for technical AHP information). The number of pair-wise comparisons is given by the following formula: where n is the number of variables

$$\frac{n(n-1)}{2} \qquad \text{Equation 1}$$

The matrix was enumerated with a linear 9-to-1 scale ranking of importance (Saaty, 1980) by comparing variables in a pair-wise fashion against one another. As proposed by Saaty (1980) a score of 9 implies absolute importance, decreasing to 1 representing equal importance). Such a scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision-maker and a discrete set of numbers which represents the importance, or weight, of the previous linguistic choices (Triantaphyllou, 2000). The priority vector was tabulated from the symmetrical matrix in order to calculate the maximum right eigenvalue (λ_{max}). Weights are determined by normalising the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix (Malczewski, 1999). Refer to Appendix A for technical information on this value. A consistency check of the priority choices was then performed to ascertain the CR as stipulated in Saaty's (1980) work. The CR was a ratio of the consistency index (CI) and the random consistency index (RI)

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad CR = \frac{CI}{RI}$$

Equation 2

The RI, as determined by Saaty, was considered to be the appropriate consistency index with which the CR could be identified. The RI where n = 7, in this case is = 1.32. The results of the CR are described in following results chapter.

The AHP was instrumental in ensuring that perceived important variables received a higher rank relative to the environmental factors that were less influential to the distribution of oribi in KwaZulu-Natal. Each factor used in the analysis was thereby given a weighting ranging from 1 to 9.

3.9 Landscape Connectivity and Corridors

3.9.1 Introduction

Habitat reduction and fragmentation at a variety of spatial scales has been widely acknowledged as a primary cause of the decline of many species worldwide (Ehrlich 1986, Lovejoy *et al.,* 1986, Harris 1984). In an effort to reduce the isolation of habitat fragments, many conservation biologists (e.g. Noss 1983, 1987, Noss and Harris 1986, Craighead *et al.,* 1997, Craighead and Vyse 1995, Paetkau et. al. 1997) have recommended maintaining landscape "connectivity" by preserving habitat for movement of species between remaining fragments. The ability of the oribi to move across landscapes is critical at many scales. A species needs to be able to move efficiently within their home ranges to access food, shelter, mates, and other basic needs (Stephens and Krebs 1986). Oribi need to be able to move beyond their home ranges to find unoccupied habitat and maintain genetic exchange between groups (Hanski and Gilpin 1997, Young and Clarke 2000). Landscape features can influence an animal's ability to move at both of these scales. Although effects will vary for different species, major road networks, harsh topography, human development, land use and land cover types all can affect an animal's ability to successfully move through an area (e.g., Beier 1995, Brody and Pelton 1989, Gibeau and Heuer 1996, McLellan and Shackleton 1988). Understanding cost distance functions and landscape linkages greatly improves our ability to maintain landscape connectivity in species with low-density populations (Clark *et al.,* 1996, Noss *et al.,* 2000, Weaver *et al.,* 1996). The methods used to ascertain landscape connectivity and corridor linkages are described in the following section under Cost Distance Procedures, Conservation Area Networks (CAN's) and potential corridor delineations.

3.9.2 Cost Distance Procedures

The objective of the cost distance analysis was to determine the least costly path to reach a source for each suitable oribi habitat cell location in the Analysis window (ESRI, 2005). The Cost Distance tool produced an output raster GRID in which each cell was assigned the accumulative cost to the closest source cell. The algorithm utilised the node/link cell representation. In the node/link representation, each centre of a cell was considered a node and each node was connected to its adjacent nodes by links. Cost functions are similar to

Euclidean functions, but instead of calculating the actual distance from one point to another, the Cost functions determine the shortest weighted distance (or accumulated travel cost) from each cell to the nearest cell in the set of source cells. The weighted distance functions apply distance in cost units, not in geographic units (ESRI, 2005).

Each suitable habitat cell has a resistance associated with it. The resistance was as a result of the suitability costs associated with the cells at each end of the link (from the cost surface i.e. Suitability Index Map) and from the direction of movement. Each land parcel (population ≥2) recorded in the oribi Geodatabase (EKZNW, 2008) with an area ≥ 160m × 160m of suitable habitat, identified in ***section 3.8*** was then used as a source cell and from here the analysis continued. The cost assigned to each cell moving away from the source represents the cost per unit distance for moving through the cell. It was therefore calculated that each cell is multiplied by the cell size (160metres) while also compensating for diagonal movement to obtain the total cost of passing through a cell. To calculate the cost to travel through each cell, the following formula was used:

"costpercell" = cost assigned to the cell * cell size

Equation 3

When moving from a cell to one of its four directly connected neighbors, the cost to move across the links to the neighboring node was one times cell 1, plus cell 2, divided by two.

$$a1 = (cost1 + cost2) / 2$$

Equation 4

Where cost1 was the cost of cell 1, cost2 was the cost of cell 2, and a1 was the total cost of the link from cell 1 to cell 2. If the movement is diagonal, the cost to travel over the link was 1.414214 (or the square root of two) times the cost of cell 1 plus the cost of cell 2, divided by two.

$$a1 = 1.414214\,(cost1 + cost2) / 2$$

Equation 5

3.9.3 Conservation Area Networks

The ***Cost Distance Analysis 3.9.1*** was a prerequisite operation for the identification of oribi Conservation Area Networks (CAN). A CAN can be defined as a definite grouping of land parcels recorded on the Oribi Geodatabase (EKZNW, 2005) with an oribi population, which are adjoining or are in a 5km suitable habitat proximity buffer of EKZNW protected areas (pers. Comm. OWG, 2006). The exact migratory parameters of the oribi are unknown due to lack of research regarding the oribi's inter and intra home range movements. The process therefore relied on a distance parameter prescribed by EKZNW ecologists. The proximity of land parcels with oribi populations to EKZNW protected areas was identified as a major constituent in the formation of a CAN (Pers. Comm. OWG, 2006). In accordance with this statement, a weighting method was used to define a CAN. The Cost weighted GRID produced in ***4.9.1*** was classified into two separate parcel groups. The first group included all EKZNW protected areas with suitable oribi habitat ≥ 160m×160m (identified in ***4.8***) and the second were the remaining private land parcels with an oribi population ≥ 2 individuals and suitable oribi habitat ≥ 160m×160m. The CAN's were identified through a method of multiplication of the private land cost distance GRID and the EKZNW protected areas cost distance GRID. The following formula was used to calculate areas that can be defined as a CAN :

"CAN"= EKZNW P.A. cost distance layer * Private cost distance layer

Equation 6

A multiplication function was used to return all adjoining parcels to EKZNW protected and discard all other areas not satisfying the parameters identified in the CAN. definition.

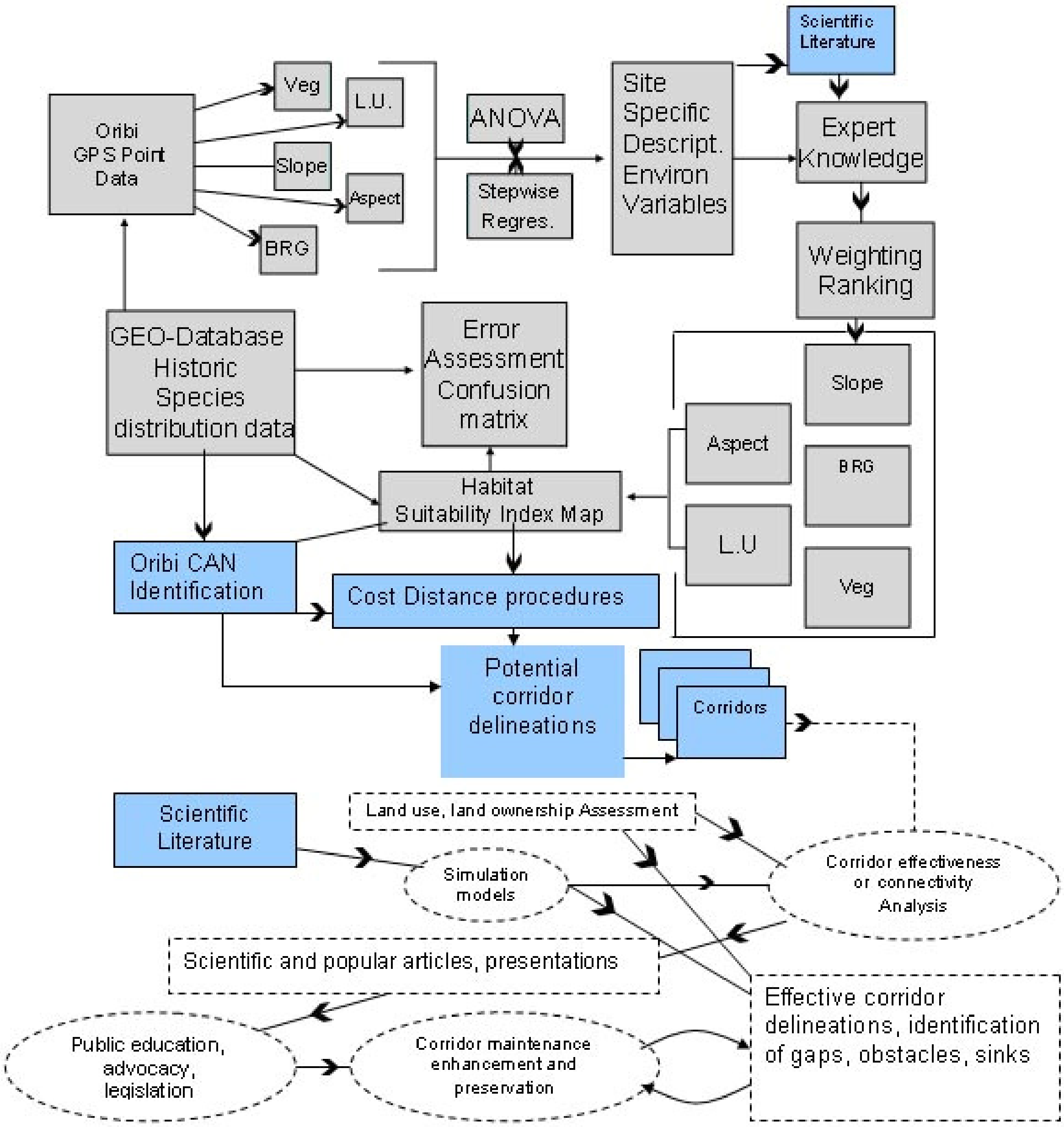

Figure 3.3 Explanatory flow chart of the methods used in the analysis

3.9.4 Potential Corridor Delineations

The potential corridors were assessed on the basis of suitability ranking, stipulated by the oribi habitat suitability model identified in the Multi Criteria Evaluation in section ***3.8*****,** and the cost distance functions of section ***3.9.1*** within the prescribed CAN's (See Figure 3.3). The corridors were identified by overlaying the reclassed cost distance GRID'S from each oribi land parcel (private and protected) over one another and identifying overlaps based on a summation of costs. The overlapping cells with the lowest costs that formed linkages between private and protected oribi land parcels. These were identified as corridors or linkage zones. The resultant GRID with the newly identified corridors or linkage zone cells was reclassed to isolate the corridors from the full extent of the GRID. The GRID linkage zones were converted from raster into vector Shapefiles using the '*convert to features'* tool in the Spatial Analyst Extension of ArcGIS 9. Working within the scope and time allowances of this study only two CAN's were investigated further and discussed. The two CAN's were selected based on percentage unit area of Highly Suitable Habitat, identified in the ***Multi Criteria Evaluation*** in section ***3.8*****,** relative to total unit area of the CAN. The two CAN's with the highest Highly Suitable unit area to total area ratio were selected for further discussion due to the directly proportional relationship between habitat suitability and oribi abundance, as determined in the ***Multivariate Data*** and ***Univariate Data analysis*** in section ***3.7 and 3.6*** respectively.

3.9.4.1 Potential Corridor Environmental Characteristics

Land management recommendations for the identified linkage zones were ascertained through a desktop investigation of environmental site characteristics of the potential corridor delineations and a review of the relevant literature. Each site was examined in accordance with parameters identified by Everett's (1991) work and corroborated with findings in the literature, then with the aid of the below mentioned characterising parameters (Table 3.3), oribi specific management recommendations were compiled (refer to Figure 3.3).

Table 3.3 Description of the environmental characteristics of the potential corridors

Environmental Characteristic	**Description**
Bioclimatic Region	As per Bioclimatic nomenclature followed by Phillips (1973).
Veld Type	Veld type was named in accordance with Acock's (1975) work.
Altitude	The average altitude, metres above sea level, for each site was calculated through an averaging function in ARCMAP using the 20m DEM.
Climate	All Meteorological data (maximum and minimum temperatures and monthly rainfall) were supplied by the South African Weather Service.
Soils	The soils were reported on in accordance with work completed by Everett (1991)

3.10 Map Algebra

3.10.1 Suitability Model Algebraic Syntax

The map calculator function was used to combine the reclassified variables in the modeling procedure.

Oribi suitability model =

("MAP" * 0.032) + ("Temperature" * 0.029) + ("Slope" * 0.282) + ("Aspect" * 0.133) + ("Landcover" * 0.343) + ("SAVEG" * 0.149) + ("BRG" * 0.03)

3.10.2 CAN Identification Syntax

Oribi CAN identification model =

(EKZNW P.A. cost distance layer) * (Private cost distance layer)

3.10.3 Potential Corridor Delineation Syntax

Potential corridor delineations =

(EKZNW P.A. cost distance layer) + (Private cost distance layer)

3.11 Suitability Model Accuracy Assessment

The accuracy assessment technique used to test the accuracy of the final oribi suitability map was an error matrix. An error matrix is an empirical estimate of the probabilistic association between remotely sensed and ancillary data versus reference data (Congalton *et al*, 1983). Overall accuracy is the total number of correctly identified oribi points (i.e. the sum of the major diagonal cells in the error matrix) divided by the total number of oribi points checked (Skidmore, 1999). The total percentage of correctly identified points was calculated using 22 test samples in the spatial model. The distribution of errors over the confusion matrix was calculated using the Kappa coefficient. The final suitability map was reclassified into four classes: HIGH, MEDIUM HIGH, MEDIUM LOW and LOW. The justification for this was that the four classes were far simpler to distinguish between than the ten classes on the final map. The ten classes produced by the modeling procedure were therefore simplified into four classes. The oribi population GPS points were reclassified into four classes rendering a basis on which a comparison and assessment could be made. The classes were as follows; 0-10=**1**, 10-20=**2**, 20-30=**3**, 30-40=**4**. The matrix was created by investigating the suitability class and the population class and then comparing the two in an error matrix grid.

Class mapping accuracy can be defined formally as:

$$M_i(\%) = \frac{N_i}{N_i + E_i} * 100$$

Where: $M_i(\%)$ = Mapping accuracy of class i
Ni = Number of correctly classified pixels in class i
Ei = Sum of omissions and commisions in class i.

A measure of agreement between image and ground truth data was originally proposed by Cohen (1960, cited in Skidmore, 1999) for use with psychological data. Kappa measures the amount of agreement between attributes and corrects for the expected amount of agreement (Bonham-Carter, 1994). Formally stated:

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i * x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i})} = \frac{\theta_1 - \theta_2}{1 - \theta_2}$$

Equation 7

Where: N is the product of marginal totals

r is the number of rows and columns in error matrix

x_{ii} is the number of observations in row 1 and column 1

x_{i+} is the marginal total of row I

x_{+1} is the marginal total of column I

$$\theta_1 = \sum_{i=1}^{r} \frac{x_{ii}}{N} \quad \text{and} \quad \theta_2 = \sum_{i=1}^{r} \frac{x_{i+}x_{+i}}{N^2}$$

Equation 8

If kappa coefficient is one or close to one then there is perfect agreement between the classified map and the reference or test data.

Chapter Four

Results

4.1 Introduction

Chapter four explores and describes the results obtained from the methods explained in Chapter 3. The results from the distribution analysis, correlation analysis, ANOVA, stepwise regression, AHP, habitat suitability map and accuracy assessment are displayed and described.

4.1.1 Variations in the data set

The variation in the dependant data set variables was measured using the Kolmogrov-Smirnov test for normality. The dependent variable in the test for normality was the total number of oribi observed at each sample site in the study area.

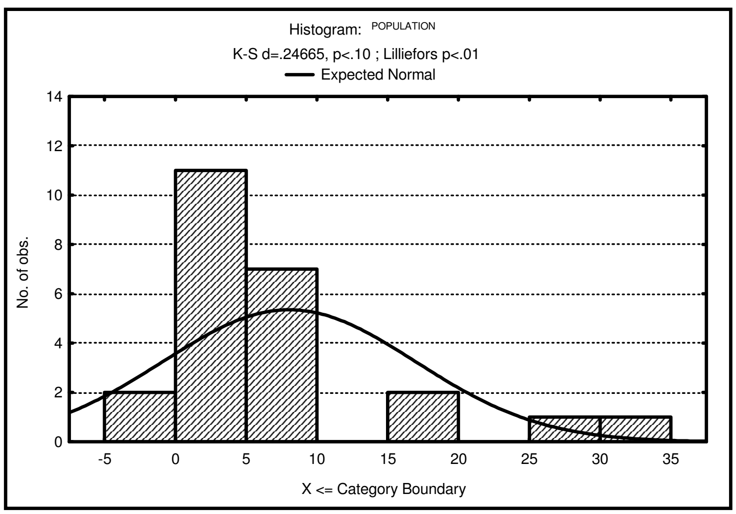

Figure 4.1 The distribution of the dependant variable measured at the oribi sample sites.

The rationale behind a normality test is data that follow a normal distribution curve can then be tested efficiently using more powerful but less robust parametric methods (Moore and McCabe, 1998). If the data are not normally distributed, then the less powerful but more robust non-parametric statistics should be used (Siegel and Castellan, 1988). It was tested whether the oribi population data is normally distributed using the Kolmogrov-Smirnov test. The null hypothesis *Ho*, was that the data is normally distributed versus the alternate hypothesis, *Ha* that the data is not normally distributed. Results of the Kolmogrov-Smirnov test showed the data to be normally distributed, p>0.05.

4.2 Environmental Data Investigation

Univariate and multivariate data analysis techniques were used to select variables that were indicative of oribi distribution. This was an important step towards selecting the input variables for suitability modeling

Table 4.1 Descriptive Statistics of the continuous data collected

Variable	Valid N	Mean	Minimum	Maximum	Std. Dev.
Population	24	8.042	0.00	35.00	8.9417
MAP	24	857.417	714.00	1101.00	96.7673
ANNTEMP	24	16.413	13.40	19.70	1.5267
Elevation	24	1133.094	160.00	1933.00	445.962

* Population = number of recording stations, MAP = Mean annual precipitation, ANNTMP = Annual average temperature, Elevation = Metres above sea level.

Table 4.2 Relationship between oribi and continuous environmental variables.

Variable	MAP	ANNTEMP	Elevation
Population	*-0.33	0.01	-0.07

- *Significant level: $p < 0.05$

4.2 Analysis of Variance results (ANOVA)

The results of the ANOVA on the categorical variables involved in the multivariate analysis are presented in the following section. This analysis was prepared in an effort to ascertain which of the environmental factors in each class rank highest and to test the significance. The results are presented in ***Table 4.3***

4.2.1 Oribi Population and Environmental Factor Classes

The one way ANOVA test was used to ascertain if there were differences in population between environmental factor classes.

The ANOVA *F* test statistic is *F* =MSG/MSE, where:

$$\text{MSG} = \frac{n_1(\overline{x}_1 - \overline{x})^2 + \cdots + n_I(\overline{x}_I - \overline{x})^2}{I - 1}$$

$$\text{MSE} = \frac{(n_1 - 1)s_1^2 + \cdots + (n_I - 1)s_I^2}{N - I}$$

ANOVA *F* tests: where *I* is the number of oribi populations, based on independent SRSs from *I* Normal populations with the same σ. *P*- values come from the *F* distribution with $I - 1$ and $N - I$ degrees of freedom, where *N* is the total observations in all samples.

We tested the null hypothesis that there is no difference in the mean value of recorded oribi population in different environmental factor classes *vs* the alternative that there is a significant difference in the mean value of oribi population in different environmental factor classes.

Stated formally:

Ho: $x_1 = x_2 = x_3 = x_n$

Ha: $x_1 \neq x_2 \neq x_3 \neq x_n$

Where x is the mean of oribi population recorded in the different environmental classes.

Table 4.3 Categorical Variables

Variable	F-value	P-value
Aspect	0.418	>0.05
Slope	1.295	<0.05**
KZN Vegetation	4.151	<0.05**
KZN Landcover	6.840	<0.05**
Bio Resource Units	0.105	>0.05

**** Significant at P <0.05**

4.2.2 Categorical Variables

As indicated by the ANOVA testing, there is a strong selection of North East facing slopes amongst the oribi sample population. Further testing established a significant selection of slopes within the 5^o-10^o degree of slope range by the same oribi sample population. There is a non selection of slopes between 0-5^o and 15^o-20^o and >20^o.

Statistical testing demonstrated that there is a high selection by oribi for the Mooi River Highland Grassland which is significantly different at $p = 0.0003$. Testing indicates a non significant selection by the oribi for the BRU-9 (Dry Highland Sourveld) with a mean that is not significantly different at $p = 0.74$. The oribi's use of Unimproved Grassland is significantly different with $p<0.05$.

4.3 Regression Summary

The results of the forward stepwise regression are a representation of the importance of the mean annual precipitation, annual average temperature and elevation to the distribution of oribi. These environmental variables were ranked using a forward stepwise regression, thereby allowing for the non-categorical variables to be weighted and ranked using the R^2 value.

4.3.1 Results

The forward stepwise regression for the dependant variable Population and the independent variables: Mean Annual Precipitation, Annual Average Temperature and Elevation revealed significant results for MAP (p=0.016). ANNTEMP and Elevation were not significant when tested (p>0.05).

4.4 Descriptions

4.4.1 Continuous variables

The correlation of continuous data and oribi population indicate the continuous variables; MAP (mean annual precipitation) is the sole significant variable at a (0.05) level of significance. This is portrayed as a strong negative correlation between MAP and oribi population data. A weak positive correlation was evident in the correlation test of oribi population and ANNTMP (annual average temperature) but this is not significant at 0.05 level of significance. A weak negative correlation was reported between oribi distribution and elevation above sea level, this correlation was not significant at $p<0.05$. The rationalisations for the results of the continuous variables are explored in detail in the discussion chapter of this report.

4.5 Weighting and Ranking Explanation

The environmental variables used in the analysis were weighted according to an AHP. The individual class factors in each environmental variable were ranked through the resulting p value from the ANOVA results, the R^2 value from the forward stepwise regression and the extensive review of the work completed on Oribi General ecology: Viljoen (1982) Reilly (1989) Everett (1991), Population ecology, habitat preferences, carrying capacities and management: Mentis (1978); Oliver, Short and Hanks (1978); Rowe-Rowe (1982a); (1982b); (1983); Rowe-Rowe and Scotcher (1986); and Marchant (1991), Status and ecology of populations: Everett (1991); Marchant (2000)

Table 4.4 Selection of factors with relative ranks

Variable	**P -Value**	**Rank**	***n***
KZN Veg (MRHGL)	0.00282**	10	13
KZN Land Cover (Unimproved Grassland)	0.0138**	10	13
Slope (5^o-10^o)	0.0486**	10	8
Aspect (NE facing)	0.0835	10	5
BRU (Dry Highland Sourveld)	0.7473	10	10

**** Significant at P <0.05**

Table 4.5.1 Standardised weighting given to the variables used in the suitability modelling.

Code	Landcover Type	Ranking
05-01-000	Unimproved Grassland	10
10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	4
02-00-000	Thicket, Bushland, Bush Clumps, High Fynbos	5
10-01-010	Cultivated Lands (permanent crops - commercial - sugar cane)	4
10-02-009	Cultivated Lands (temporary crops - subsistence - dryland)	8
10-02-006	Cultivated Lands (permanent crops - commercial - irrigated)	3
01-01-001	Forest (Indigenous)	1
Nil	Water bodies	0
Nil	Wetlands	0
Nil	Bare Rock and Soil (natural/erosion: dongas/gullies/sheet)	0
Nil	Forest Plantations (Exotic Spp.)	0
Nil	Urban Built Up (residential/industrial/transport/rural/education/health)	0
Nil	Mines and Quarries (Surface Based Mines)	0

Code	Aspect Class	Ranking
S	South facing	3
N	North facing	2
E	East facing	3
SE	South East facing	3
NW	North West facing	3
NE	North East facing	10
SW	South West facing	1
W	West facing	2
Code	Slope Class	Ranking
1	0-5	6
2	5-10	10
3	10-15	4
4	15-20	4
5	>20	4
Code	KwaZulu-Natal Vegetation Type	Ranking
LEMG	Low Escarpment Moist Grassland	4
NKZNMG	Northern KwaZulu-Natal Moist Grassland	4
MMGL	Midlands Mistbelt Grassland	5
PNSCS	Pondoland-Natal Sandstone Coastal Sourveld	5
MRHGL	Mooi River Highland Grassland	10
GMGL	Glencoe Moist Grassland	7
SCGL	South Coast Grassland	4
DNVELD	Dry Ngongoni Veld	4
EGGL	East Griqualand Grassland	2
TUGTH	Thukela Thornveld	2
KZNHTH	KwaZulu-Natal Highland Thornveld	5
DFMGL	Drakensberg Foothill Moist Grassland	4
MNVELD	Moist Ngongoni Veld	3

Code	Bio Resource Group	Ranking
1	Moist Coast Forest, Thorn & Palm Veld	6
3	Moist Coast Hinterland Ngongoni Veld	3
4	Dry Coast Hinterland Ngongoni Veld	4
5	Moist Midlands Mistbelt	6
8	Moist Highland Sourveld	4
9	Dry Highveld Sourveld	10
11	Moist Transitional Tall Grassland	8
12	Moist Tall Grassland	3
13	Dry Tall Grassland	5
18	Mixed Thornveld	6
Code	Mean Annual Precipitation Class	Ranking
<714	<714mm (MAP)	2
714-1101	714mm (MAP) to 1101mm (MAP)	10
>1101	>1101 (MAP)	2
Code	Annual Average Temperature Class	Ranking
<13.4	<13.4 ^{o}C (Annual Average Temperature)	2
13.4-19.7	13.4-19.7 ^{o}C (Annual Average Temperature)	10
>19.7	>19.7 ^{o}C (Annual Average Temperature)	3

4.6 Class Weights

The weights given to each class were assigned through an AHP subsequent to a rigorous review of relevant oribi literature, including general oribi ecology: Viljoen (1982) Reilly (1989) Everett (1991), population ecology, habitat preferences, carrying capacities and management: Mentis (1978); Oliver, Short and Hanks (1978); Rowe-Rowe (1982a); (1982b); (1983); Rowe-Rowe and Scotcher (1986); and Marchant (1991), Status and ecology of populations: Everett (1991); Marchant (2000). The complete pair-wise comparison matrix, basic priority ratings and final calculated weights for all class group variables are summarised in Table 4.6.1 and Table 4.6.2, including the consistency ratio in the final run. The CR obtained in this case proved to be in an acceptable range (i.e. CR< 0.10). The weights per variable sum to one, as is required by the weighted linear combination procedures.

Table 4.6.1 The variable class pair-wise comparison matrix

Variable Class	MAP	ANN TEMP	BRG	kzn VEG	kzn Landcover	Slope	Aspect
MAP	1	2	1/2	1/4	1/8	1/9	1/7
ANN TEMP	1/2	1	2	1/7	1/9	1/9	1/7
BRG	2	1/2	1	1/7	1/9	1/9	1/7
KZN VEG	4	7	7	1	1/3	1/3	2
KZN Landcover	8	9	9	3	1	2	4
Slope	9	9	9	3	1/2	1	4
Aspect	7	7	7	1/2	1/4	1/4	1
SUM	31.5	35.5	35 1/2	8	2 3/7	4	11 3/7

Table 4.6.2 The relative weights and priorities given to each variable class

Variable Class	Explanation	Weight
LANDCOVER	KwaZulu-Natal Land Cover	0.3438
SLOPE	Slope	0.2824
KZNVEG	KwaZulu-Natal Vegetation	0.1490
ASPECT	Aspect	0.1333
MAP	Mean Annual Precipitation	0.0322
BRG	Bio Resource Group	0.0300
ANNTEMP	Annual Average Temperature	0.0292
SUM		**1.0000**
Consistency Ratio	Degree of consistency in the pair-wise comparisons	**0.0987**

4.7 Oribi Habitat Suitability Model

The habitat suitability model that was created by the process outlined in Chapter Four was the final output of the modelling process and is displayed as a suitability map in ***figure 4.7.1.*** The figure shows the areas with high suitability as red, medium high as yellow, medium low as cyan and low as blue.

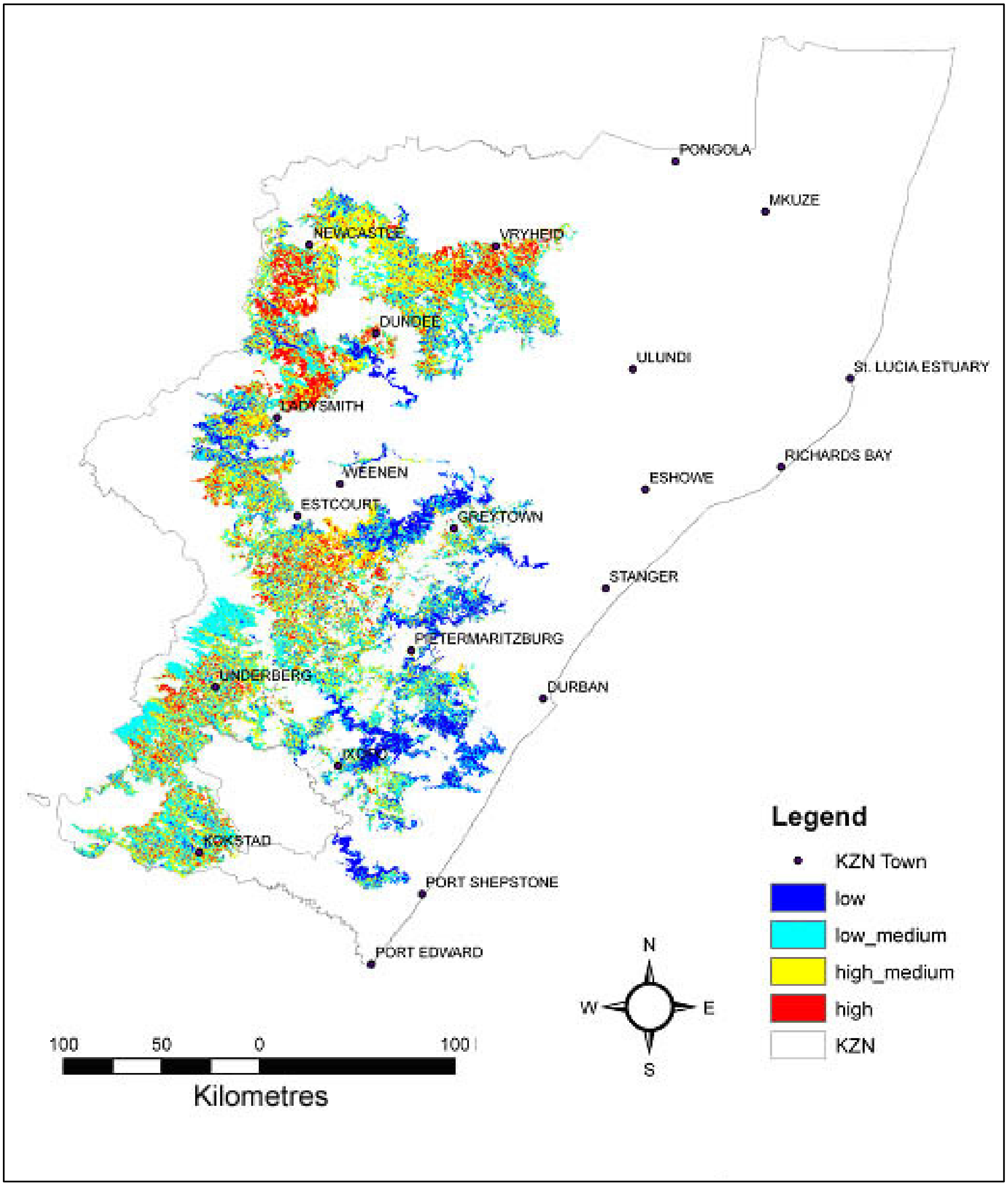

Figure 4.7.1 Oribi habitat Suitability Index Map of KwaZulu-Natal

4.7.1 Oribi Habitat Suitability Map Description

The Habitat Suitability Map results depict a large area of HIGH suitability south of Newcastle in the region of the Ezemvelo KZN Wildlife reserve of Chelmsford. Similarly there is another area of HIGH suitability north east of Ladysmith. South of Vryheid in Northern KwaZulu-Natal, the model returned this extensive area with a HIGH suitability.

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Figure 4.7.2; *Habitat Suitability Index (1-4)*, 4 being most suitable and the respective amount of area (ha) for each suitability class over the study area of KZN

*Area Calculation: (Count * Cell Area)= # of hectares*

The results of the habitat suitability analysis reveal that the Classes with the highest area are class two and three with 842798 ha and 795502 ha respectively. Conversely the class with the lowest area count is that of class four with 189708 ha.

4.8 Landscape Connectivity and Corridors

The results of the analysis and procedures in Chapter Three regarding the identification of the oribi CANs and corridors or linkage zone are presented in sections ***4.8.1*** and ***4.8.2***

4.8.1 Cost distance Procedures

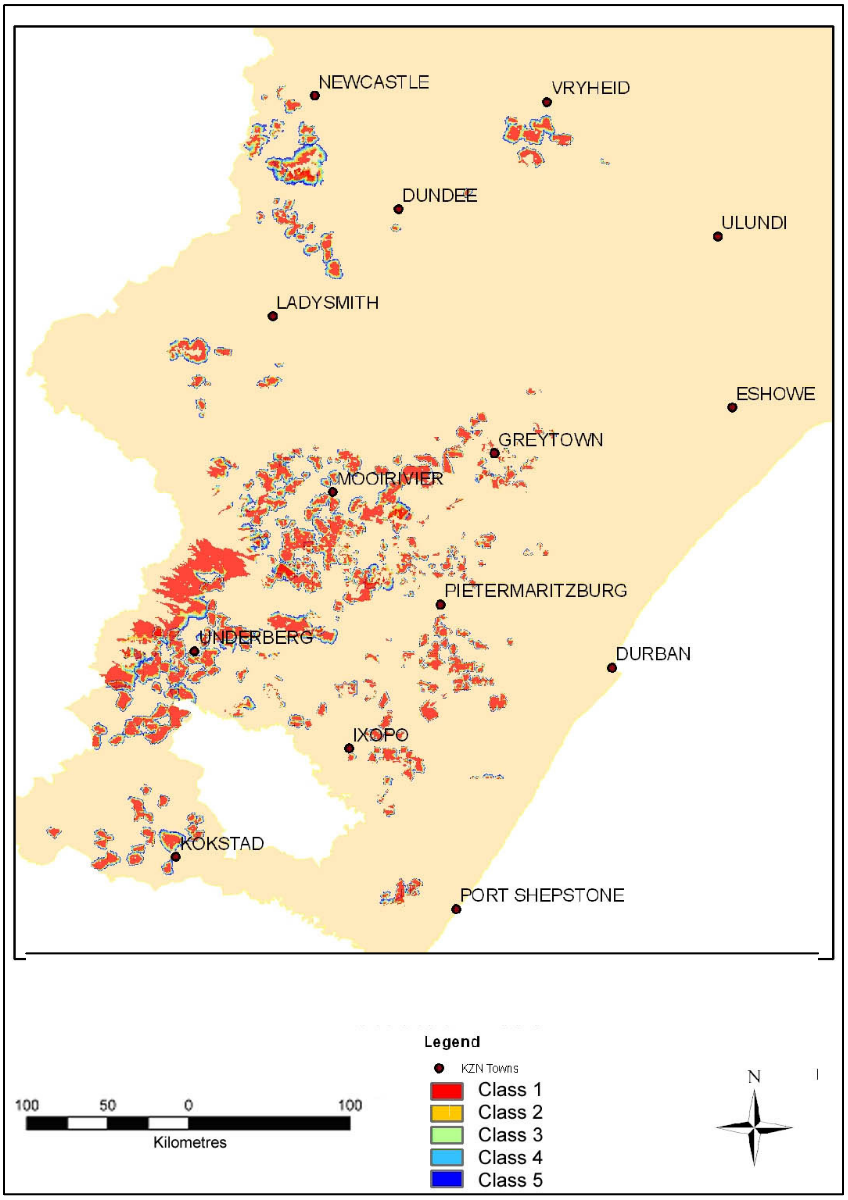

Figure 4.7.3 The Cost Distance Analysis on private and protected areas in KwaZulu Natal.

The cost of movement (on a scale of 1-5) encountered by the oribi is based on the suitability of the habitat and the distance travelled. The red zones are land that was returned by the cost distance procedure to be of least cost to oribi movement and have a cost value of 1.The zones represented by dark blue have the highest cost value for oribi movement returned by the cost distance procedures.

4.8.2 Conservation Area Networks

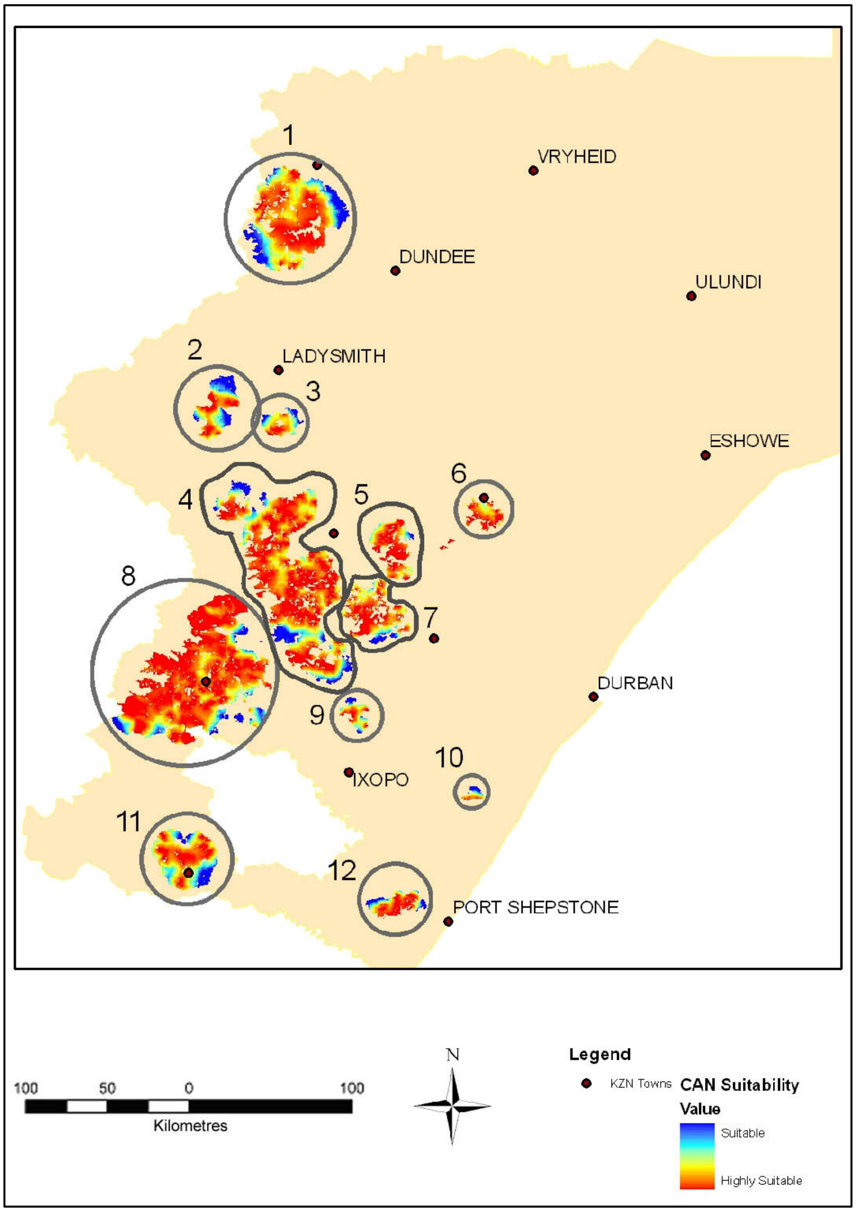

Figure 4.8 The Oribi Conservation Area Networks in KwaZulu-Natal.

The numerical identifiers from 1 to 12 indicate the CAN number and are described in ***table 4.7.1***. The suitability ranking of each CAN was as a result of Euclidian distance from EKZNW protected areas, private land (see ***Cost Distance Procedures 3.9.1)*** and habitat suitability (see ***figure 4.7.1***.)

Table 4.7.1, The details of the 12 proposed oribi CANs in KwaZulu-Natal are presented in the table below. Each CAN reference number listed corresponds to those in ***Figure 4.8.2***

	Suitability	Count	Area (Ha)	% of total	Abundance 2005 (excl EKZNW)
CAN 1	1	1156	2959.36	3.36	120
	2	7037	18014.72	20.47	
	3	12094	30960.64	35.18	
	4	14086	36060.16	40.98	
Total			87994.88		
CAN 2	1	2243	5742.08	24.76	3
	2	2709	6935.04	29.91	
	3	3126	8002.56	34.51	
	4	980	2508.8	10.82	
Total			23188.48		
CAN 3	1	449	1149.44	11.47	3
	2	1134	2903.04	28.98	
	3	1729	4426.24	44.19	
	4	601	1538.56	15.36	
Total			10017.28		
CAN 4	1	2737	7006.72	4.73	428
	2	21802	55813.12	37.66	
	3	22913	58657.28	39.58	
	4	10445	26739.2	18.04	
Total			148216.32		
CAN 5	1	407	1041.92	5.32	135
	2	1764	4515.84	23.04	
	3	3548	9082.88	46.35	
	4	1936	4956.16	25.29	
Total			19596.8		
CAN 6	1	362	926.72	10.54	123
	2	1288	3297.28	37.49	
	3	1440	3686.4	41.91	
	4	346	885.76	10.07	
Total			8796.16		

	Suitability	Count	Area (Ha)	% of Total	Abundance 2005 (excl EKZNW)
CAN 7	1	915	2342.4	8.86	63
	2	4261	10908.16	41.25	
	3	3920	10035.2	37.95	
	4	1233	3156.48	11.94	
Total			26442.24		
CAN 8	1	1110	2841.6	1.73	129
	2	30540	78182.4	47.72	
	3	22212	56862.72	34.71	
	4	10132	25937.92	15.83	
Total			163824.64		
CAN 9	1	1804	4618.24	62.62	29
	2	957	2449.92	33.22	
	3	113	289.28	3.92	
	4	7	17.92	0.24	
Total			7375.36		
CAN 10	1	612	1566.72	62.07	2
	2	355	908.8	36.00	
	3	18	46.08	1.83	
	4	1	2.56	0.10	
Total			2524.16		
CAN 11	1	1115	2854.4	7.08	130
	2	7370	18867.2	46.79	
	3	5348	13690.88	33.96	
	4	1917	4907.52	12.17	
Total			40320		
CAN 12	1	2220	5683.2	43.38	91
	2	1939	4963.84	37.89	
	3	843	2158.08	16.47	
	4	116	296.96	2.27	
Total			13102.08		

4.9 CAN Result Description

The CAN with the largest area is **CAN 8** with **163824.64 ha**. The CAN with the smallest area is **CAN 10** with **2524.16 ha**. **CAN 1** has the highest percentage of **4** suitability rating relative to the total area in that CAN with **40.98%**. The CAN with the highest percentage of **1** suitability rating is **CAN 9** with **62.62%.** The **Abundance** column presents the number of oribi individuals counted on private lands during the 2005 oribi census. The **Count** column represents the total sum of 160m x 160m cells reported within each individual CAN. The **Suitability** column is the suitability rating of the habitat according to the ***Oribi Suitability Index Map 4.7.1***

4.9.1 Potential Corridor Delineations Results

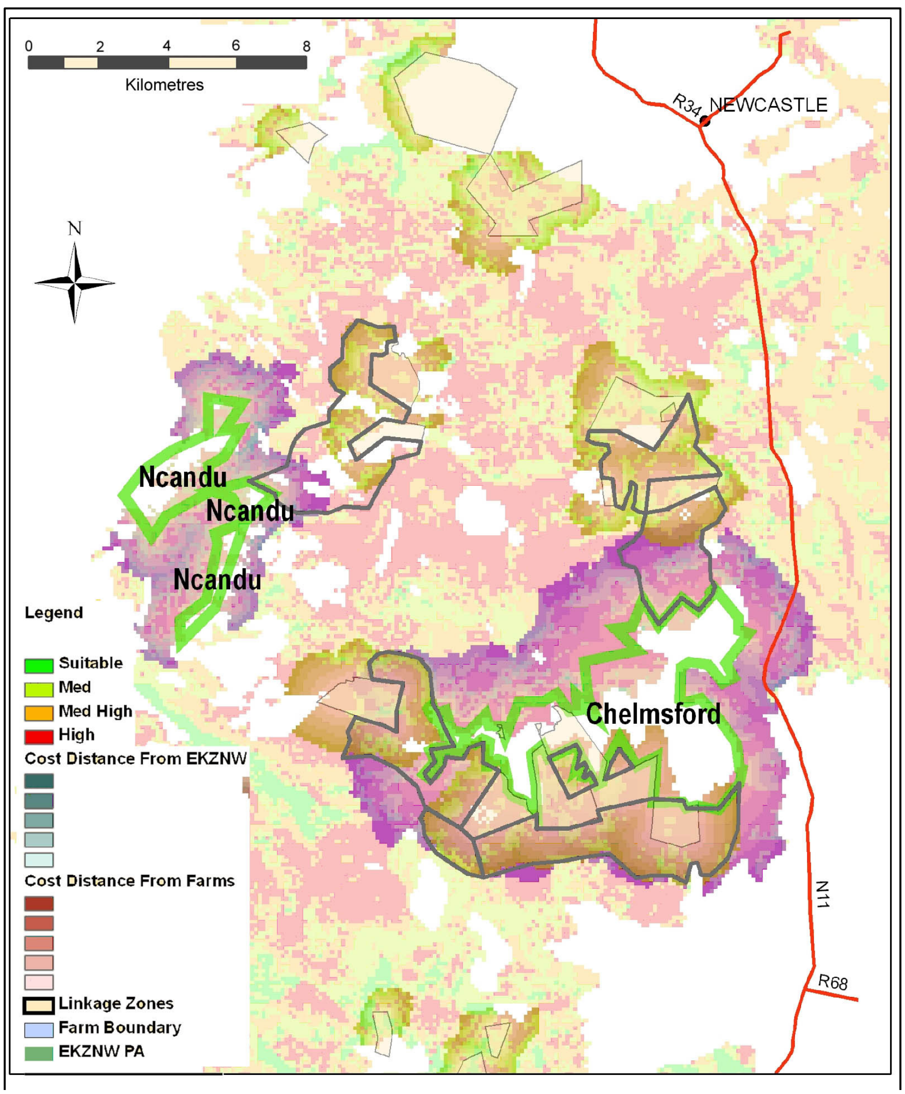

Figure 4.9. Corridor delineations in the Chelmsford region (CAN 1) are represented in this figure by dark grey outlines.

The delineated zones were areas identified through the process described in section ***3.9.3 Potential Corridor Delineations***. In the Chelmsford region, the linkage zone with the smallest area was 68.9 ha. The largest linkage zone has an area of 2570.1 ha. The total sum of the linkage zone areas was 10378 ha out of a total CAN area of 87994.88 ha.

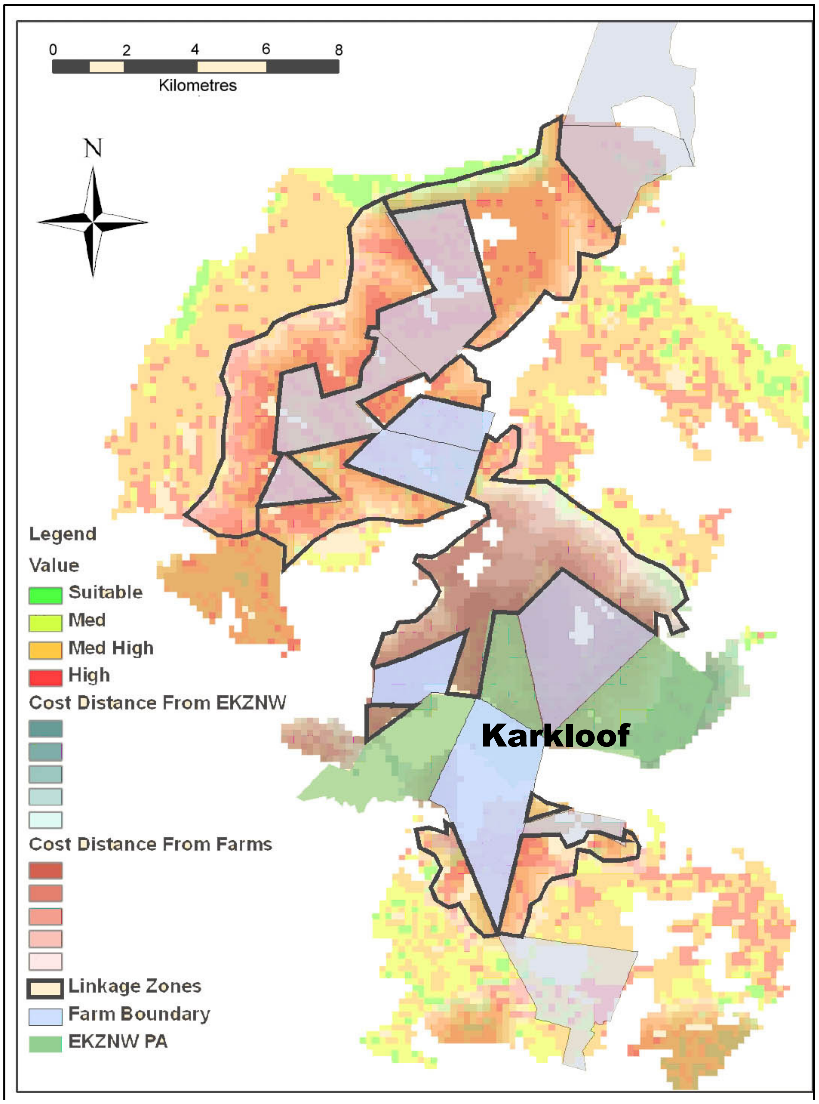

Figure 4.10. Corridor delineations for CAN 5 adjoining the protected area of Karkloof Nature Reserve.

These linkage zones are depicted by the framed solid black lines in the above mentioned figure. The largest zone was 1494.9 ha and conversely the smallest linkage zone in CAN 5 was 29.5 ha. The sum total area of the linkage zones in CAN 5 was 6004 ha out of a total CAN area of 19596.8 ha

4.9.2 Corridor Environmental Characteristics

The results of the desktop investigation into the potential corridor site characteristics are reported below. Each site was examined in accordance with parameters identified by Everett's (1991) work, and then with the aid of relevant management literature, oribi specific management recommendations were reported in Chapter Five.

Table 4.7.2 Linkage Zone Characteristics

Environmental Characteristic	**Karkloof**	**Chelmsford**
Bioclimatic Region	(4) Highland	(6) Upland, Moister type
Veld Type	Highland Sourveld	Southern Tall Grassland
Altitude (m)	900-1650	1200-1300
Climate		
MAP (mm)	741	915
Monthly MAP Distribution	All Months, 88%Sep-Mar	All Months, 82%Oct-Mar
Summer Temp (oC):Mean min	16	13
Mean max	29	24
Winter Temp (oC): Mean min	5	5
Mean max	22	18
Soils	Undifferentiated red and	Dystrophic to Mesotrophic
	yellow Dystrophic	High in clay, not sandy

Table 4.7.3 Description of terms for Linkage Zones

Term	**Description**
Bioclimatic Region	Classification of the natural resources of KwaZulu-Natal into 11 bioclimatic groups for pasture production guidelines (Phillips, 1969).
Veld Type	Classification of veld types for South Africa (Acocks 1975)
Altitude	The average altitude, meters above sea level, for each site was calculated through an averaging function in ARCMAP using 20m DEM.
Climate	Meteorological data (maximum and minimum temperatures and monthly rainfall distribution) were supplied by the South African Weather Service.
Soils	Soils were reported on in accordance with Land Types South African (ARC 2006)

4.10 Suitability Model Accuracy Assessment

4.10.1 Error Matrix and Kappa

Table 4.8.1 The Error matrix accuracy assessment of the final oribi habitat suitability model

Class	1	2	3	4	**Row Total**	**Commission Error**	**User Accuracy**
1	9	0	0	0	**9**	**0**	**1**
2	3	3	0	0	**6**	**0.5**	**0.5**
3	0	0	0	0	**0**	**0**	**0**
4	3	2	0	2	**7**	**0.71**	**0.29**
Column Total	**15**	**5**	**0**	**2**	**14**		
Omission Error	**0.35**	**0.4**	**0**	**0**		**63.64**	
Producer accuracy	**0.6**	**0.6**	**0**	**1**			

N = 22

$$\sum_{i=1}^{r} x_{ii} = 9+3+0+2=14$$

Overall Accuracy = 14/22= 63.64%

$$\sum_{i=1}^{r} (x_{i+} * x_{+i}) = (15*9)+(5*6)+(0*0)+(2*7)= 179$$

$$\text{Therefore K} = \frac{(22*14)-179}{22^2-179} = 0.42$$

Chapter five

Discussion and Management Recommendations

5.1 Introduction

This chapter discusses the findings from Chapter Four and presents management recommendations. The Oribi Habitat Suitability Model will be explained in detail, the Conservation Area Networks (CANs), their formulation and management will be discussed and the proposed corridor delineations within the CANs will be expanded upon.

5.2 Oribi Habitat

Oribi selected the north easterly slopes rather than the south facing and westerly slopes. One can attribute this to the predominantly drier and warmer climates experienced on the northern and eastern slopes (Perrin and Everett, 1999). The veld composition would tend to be dominated by "sweeter" grass species, i.e. those grass species which are palatable for the entire year and would maintain the animals' condition throughout the year, and which are more palatable to grazing herbivores such as the oribi (Tainton, 1981).

Oribi show a strong selection for slopes that fall within the 2nd slope class of (5^{o}-10^{o}). These slopes are generally associated with soils that are well drained, well aerated and oxidised and are preconditions for a high quality veld (Jenny, 1980). The oribi tend to avoid steeper slopes >10^{o}, a factor which is probably linked to the oribi's limited ability in utilising the steeper slopes for grazing or cover. The avoidance of flat slopes (0^{o}-5^{o}) by the oribi could be related to the heavier soils and poorer drainage conditions normally found on flat land (as cited in Perrin and Everett, 1999). Everett (1991) believes that the soils found on these slopes do not produce the grass species preferred by the oribi and therefore is not the preferred habitat of the oribi. The results from the land cover analysis demonstrate a significant selection by the oribi for unimproved grassland land cover. This is significant as these findings corroborate those of other authors. The oribi is generally recognised as a species occupying Unimproved Grassland (Tait 1963; Thompson 1973; Jarman 1974; Oliver *et al.,* 1978; Viljoen 1975; Rowe-Rowe 1983; Smithers 1983; Reilly 1989 and Everett 1991). The results found here confirm the selection of grassland by oribi. No other authors have recorded observations on selection, by oribi, of other vegetation. The significant negative correlation between mean annual precipitation and oribi distribution can be related to the oribi's selective feeding. Oribi will tend to feed on high quality species or green shoots (Tainton, 1981). Areas of high rainfall and absence of fire will be less suitable for grazing due to the positive effect rainfall has on biomass as *Podocarpus* forests encroach in Highland Sourveld regions (Camp, 1997).

5.3 Model Discussion

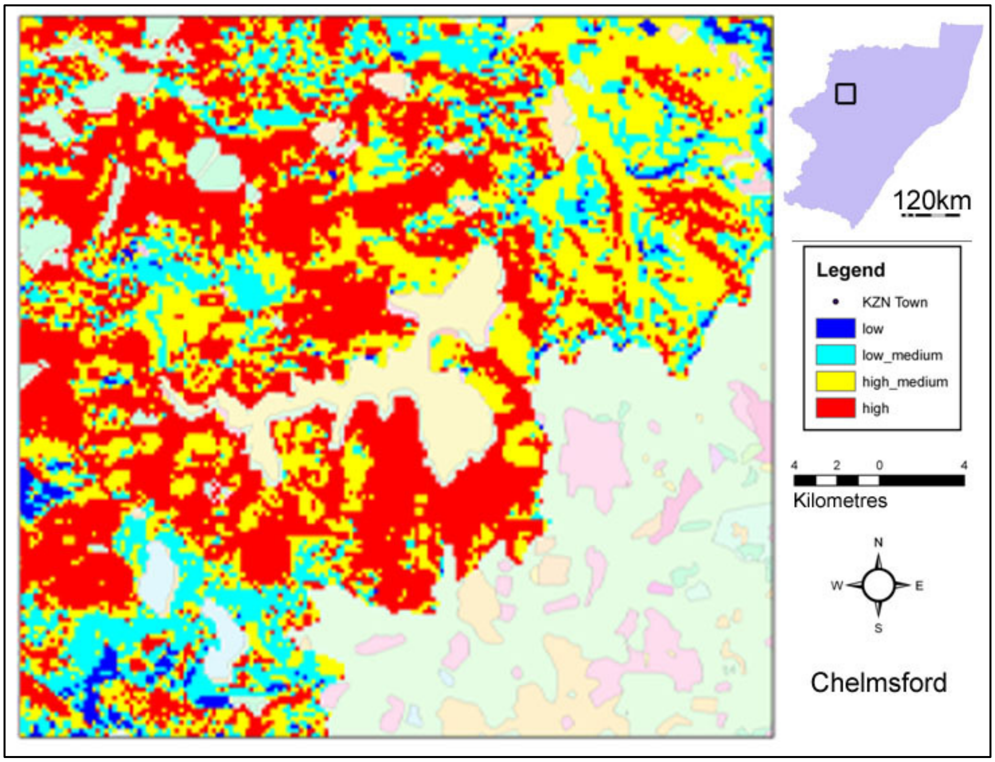

Figure 5.1 Chelmsford Nature Reserve with KZN map inset

5.3.1 Chelmsford

The Chelmsford Nature Reserve and surroundings were identified as areas with a high suitability ranking (see ***figure 4.7.1***). The vector colour inset surrounding the red and yellow raster cells on the left map is a water body and falls within the boundary of the Chelmsford Nature Reserve. The reserve is 724 ha in extent and ranges in altitude from 1240 – 1290m (EKZNW, 2005). The prevalence of 5-10 degree slopes and the Dry

Highland Sourveld gave this area a high rating in the habitat suitability ranking. The farms surrounding the nature reserve in this zone must be considered integral to the survival of the oribi. This map highlights the importance of the relationship between Ezemvelo KZN Wildlife and the private landowners culminating in an effort to conserve the declining oribi population through connectivity of suitable habitat. **Section 5.4** will discuss suitable habitat connectivity within this area.

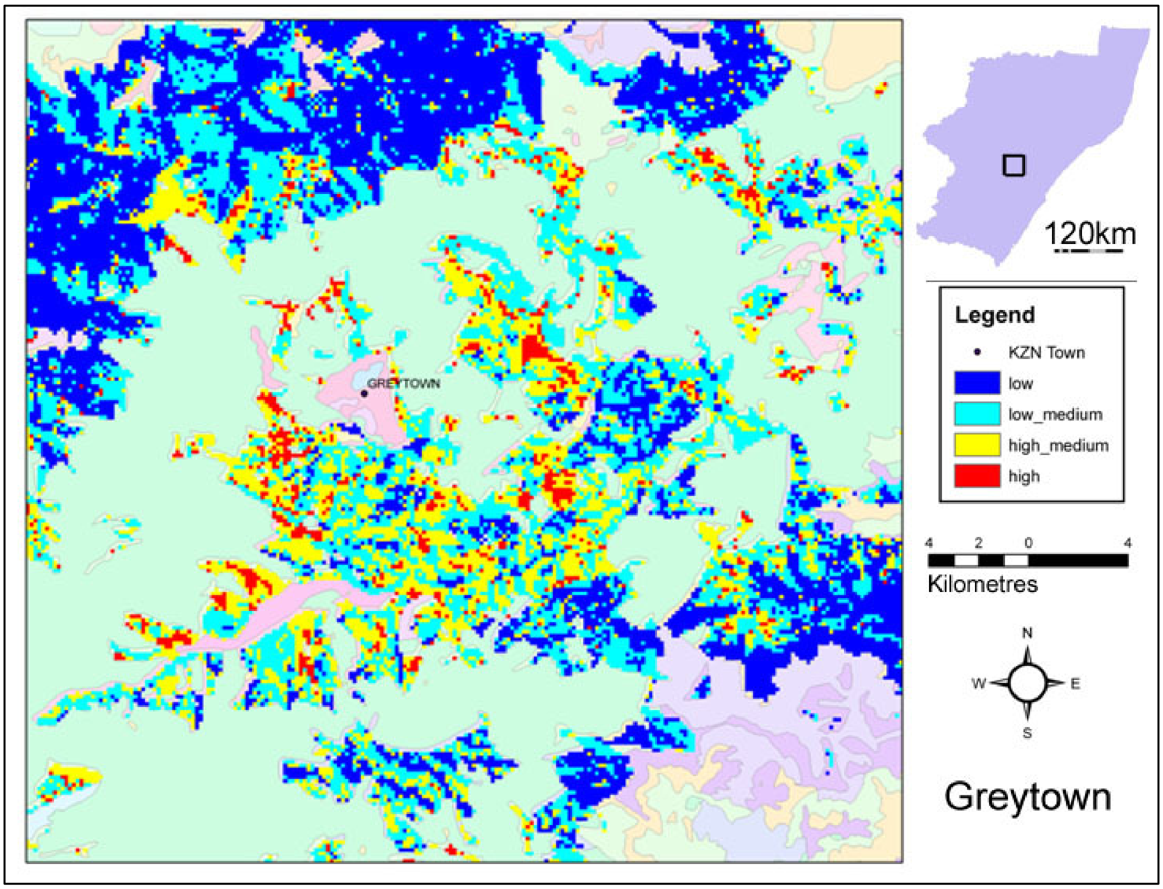

Figure 5.3 Greytown and surrounds with KZN inset

5.3.2 Greytown

The town of Greytown is situated north east of Pietermaritzburg and is recognised as a timber farming region. ***Figure 5.4*** visually emphasises one of the principal concerns raised by Marchant (2000), that being habitat fragmentation. The figure on the right depicts a scattering of 2 to 3 hectare blocks with high (red) suitability surrounded by areas of low suitability (blue) and plantations (green). Plantations are not selected by the oribi as a habitat (Everett, 1991). The disjointing of suitable oribi habitat will inevitably lead to further habitat fragmentation if residual grassland patches are converted into plantations. Oribi require between 34 ha and 49 ha (Coverdale, *et al*. 2006) as territory and this poses a habitat scarcity problem for the above mentioned area if suitable grasslands are not conserved. The extensive habitat fragmentation in this region of KZN needs to become a concern to land owners if the oribi are to survive future generations.

5.4 Landscape Connectivity and Corridors

Inaugurating habitat connectivity between fragmented suitable habitat areas through cost distance analysis was an integral step towards formulating the Oribi Conservation Area Networks in KZN. The subsequent identification of twelve oribi CANs, see ***figure 4.8***, formalised an agglomeration effort to link fragmented and isolated oribi populations. The regrouping of the isolated populations will therefore concentrate conservation efforts led by the OWG and EKZNW and spearhead the implementation of oribi-related management practices at ground level.

5.4.1 CAN Discussion

CAN 1 and CAN 5 formed the basis for the CAN discussion and are examined in the following section. CAN 1 returned the highest percentage area of level 4 suitability out of the twelve CANs. A reported 40.98% of the CAN area was ranked as level 4 (HIGH) suitability out of a total of 87994.88 ha. The CAN with the second highest level 4 suitability was CAN 5 with 25.29% reported for the total area of 19596.8 ha.

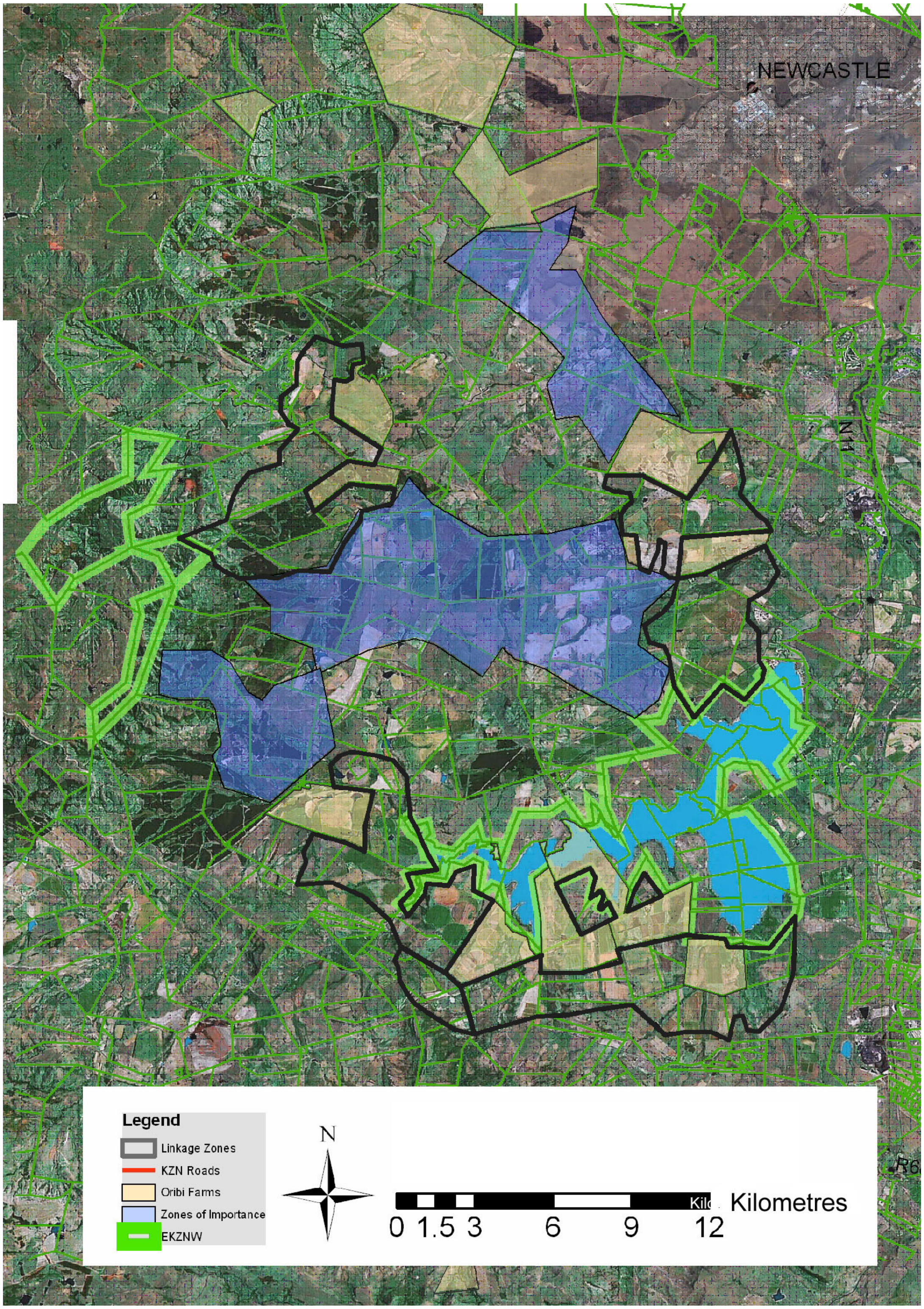

Figure 5.6 CAN 1 in the Chelmsford region of KZN, (after ***Figure 4.9)***

5.4.1.1 Chelmsford CAN Discussion

The Chelmsford CAN has a 15.69% greater abundance of level 4 suitability than any other CAN in KZN (see ***figure 4.7.1***). This can be attributed to the large uninterrupted Moist Transitional Grasslands (Edwards, 1967) and Highlands Sourveld (Acocks, 1975) evident in this CAN, both of which are favoured by oribi (Everett, 1991). It is predominately for this reason that Chelmsford must become a priority CAN within planning structures where the collective aim is ultimately to sustain oribi populations. The Chelmsford area depicted is ideally suited to maintain a healthy and viable subpopulation greater than 90 individuals as per PHVA guidelines (Coverdale, *et al*, 2006). It is therefore in the best interest of conservation authorities that a CAN be formulated around Chelmsford Nature Reserve (CNR). In terms of oribi movement in and around CNR expelled oribi rams are not confined to contracting territories due to unfavourable human initiated practices, and are free to move to open territories. In a managed environment such as the CNR an oribi population will naturally maintain itself (Coverdale, *et al*, 2006).

The proposed linkage zones depicted in ***figure 5.6*** collectively link the private farms, the CNR and the Nqandu Nature Reserve (NNR). Zones depicted by a blue transparent overlay are areas that were identified by visual interpretation of ***figure 4.7.1*** with expert knowledge. The above mentioned areas were not identified via the linkage zone calculations described in Chapter Four and presented in Chapter Five but were visually identified as zones of importance through expert knowledge (OWG, 2007 Pers. Comm.). A zone of importance was defined as zone that conservation authorities will earmark when considering future land use planning in the area adjoining the CAN, but this is out of the scope of this project and will need future research to confirm the efficacy of such zones in oribi habitat conservation.

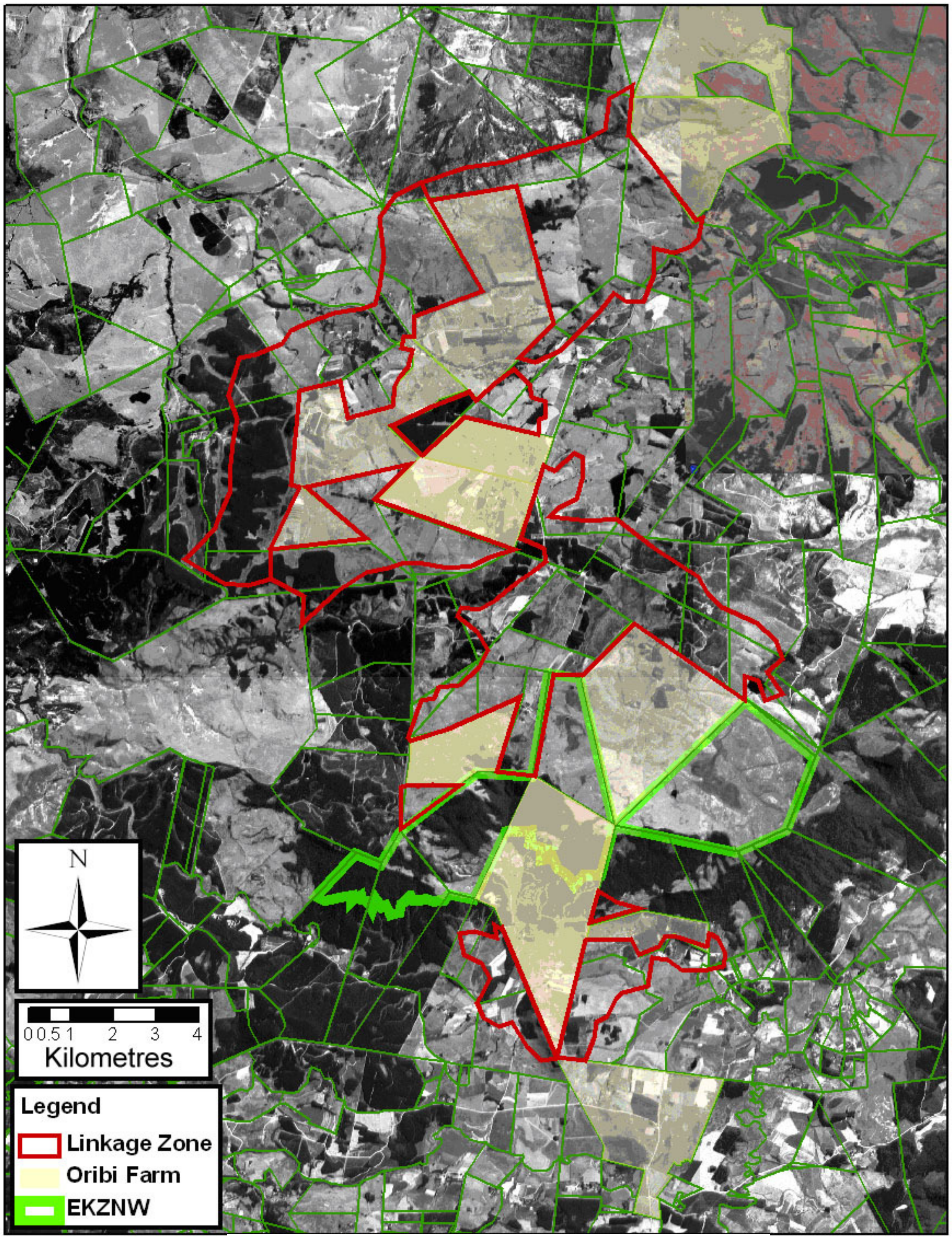

Figure 5.7 CAN 5 in the Karkloof Area (after ***Figure 4.10***)

5.4.1.2 Karkloof CAN Discussion

The Karkloof CAN has the second highest count of level 4 suitability of all the proposed Oribi CANs, see ***figure 4.8***. The Karkloof Nature Reserve (KNR) was delineated by a light green boundary and represents a total reserve area of 1934 ha out of a total CAN area of 19596.8 ha. The current KNR is characterised by indigenous forest and was classified by Moll (1969) and Cooper (1985) as Afromontane Mistbelt mixed *Podocarpus* forest which occurs between 1000m and 1300 to 1500m, on steep south-facing slopes (Moll, 1969; Cooper, 1985). As represented in ***figure 4.8,*** 1175 ha of the total reserve is Suitable to Highly Suitable for oribi inhabitation; the remainder is mixed Afromontane forest. The residual Moist Highland Sourveld (Camp, 1997) grassland patches are highly suitable for oribi habitation (Camp, 1997; Everett, 1991), see ***figure 4.2.6,*** but are highly fragmented by way of exotic plantations and indigenous Afromontane forests depicted in this figure. In ***Figure 5.7***, both indigenous forest and exotic plantations are displayed as dark black uniform extents and cover much of the figures mid to lower areas. Intra CAN movement is limited or inhibited by barriers such as those identified in ***figure 5.2*** but oribi specific grassland corridors can form effective linkages and decrease the occurrence of isolated grassland islands.

The Linkage zones identified in ***Figures 5.6 and 5.7*** were calculated using the methods described in Chapter Four. As mentioned in Chapter Four the zones were identified using the habitat suitability index, and this index did not take into consideration barriers to movement such as fences, roads or canals. It is therefore reiterated that this assessment was intended to provide information for developing conservation strategies, to contribute to future field survey efforts, and to help identify management priorities. These analyses were conducted using regional-scale spatial data sets that are effective for evaluating broad-scale patterns but should not be expected to provide precise information for specific locations on the ground.

5.5 Habitat Management Recommendations

Oribi population density is directly determined by the amount of suitable habitat, the quality and quantity of food, and the management policy of a grassland area (Everett, 1991). It is therefore critical to control the manageable environmental variables to maximise oribi population stability. Investigations into reported advantageous oribi-specific grassland management recommendations were undertaken for each CAN and the identified linkage zones. The recommendations were reported in the following section.

5.5.1 Managing with Fire, Mowing and Grazing

The Chelmsford CAN and Karkloof CAN are both situated in a Sourveld veld type Region (veld which provides palatable material only in the growing season – Tainton 1981). Rainfall in both the Chelmsford and Karkloof geographic regions is classified as high, seasonal and predictable (Everett, 1991).In this region the production of herbage material is high and must be controlled through the informed use of fire and mowing for optimal oribi populations (mentis 1978; Oliver *et al.,* 1978 Scotcher, Clark and Lowry, 1980; Rowe-Rowe, 1982a; Shackleton and Walker, 1985; Everett, 1991). Fire is considered the single most important ecological factor determining the presence and extent of the grassland biome in South Africa (O'Connor and Bredenkamp 1997). Oliver *et al.,* (1978) found that grass burnt during June contained almost double the amount of crude protein in August compared to unburnt areas at the same period (Rowe-Rowe and Scotchern, 1986). As a result, oribi in these sourveld CANs have a marked preference for burns in June, July and August (Oliver *et al.,* 1978). The use of burning and mowing as management inputs may limit the nutrient stress on the oribi in the autumn and winter (Everett, 1991) In order to provide oribi with a superior quality crucial winter fodder, Everett (1991) considers a biennial autumn burn to be most advantageous for oribi in the short term but warns the damage to the veld in the long term is likely to be excessive. Tainton and Mentis (1984) argue that the use of fire to maintain the grassland should be restricted to the dormant winter or early spring period. Burning later in spring, once the growth has commenced, leads to severe damage to the grass cover and exposes the soil to the first summer rains and results in higher predicted sediment losses than does annual winter burning. The most suitable compromise in this instance would be a biennial spring or late winter burn, combined with the provision of mowed areas, and wide fire breaks burnt in autumn. As previously discussed oribi require both short (0.1-0.5m) and longer (0.5-1.5m) grass zones for optimal survival (Everett, 1991). A selection of short grass areas for feeding and longer grass areas for resting must be taking into account when considering management practices. It is important to note that oribi use long grass areas for resting, predatoravoidance, and the concealment of young which lie out in the veld for at least six weeks after birth (Viljeon, 1975; Oliver *et al.,* 1978). Emphasis must be placed on the use of management practices which ensure sufficient vegetation cover remains. This can be achieved with a burning configuration that obtains a mosaic pattern over the managed grassland extent. Therefore a proposed biennial winter burn is recommended so as to provide forage with high nutrient content during the late winter, as well as promoting the growth of *Themeda triandra*, an oribi-preferred species (Shackleton and Walker, 1985).

The general topography of both CANs and surrounding land, lends itself to extensive farming (Camp, 1995). Everett's work corroborates with that of Marchant (Personal comm.) where oribi are known to benefit from an extensive form of cattle farming, as grazing cattle facilitate the exposure of shorter grasses ideal for oribi grazing (Everett, 1991). If defoliation through cattle grazing is not possible a similar effect can be obtained through mowing. In reality the abundance and impact of large herbivores is not uniform across the grassland biome and varies in relation to the local rainfall and soil characteristics of the CANs (Bell, 1982). Taking cognisance of such environment variations, when considering grazing as a management tool, will aid mowing and burning management decisions over the extent of both CANs. Fynn *et al* (2003) remarks that grazing intensity will have the most impact of the grazing variables on biodiversity integrity, and extent of grazing the least. Grazing intensity relates to stocking rate, and is thus more of a reflection of management than of grazing system. Although High Intensity Grazing systems will have, on average, a greater negative impact on grassland biodiversity integrity than 'average' conventional or continuous systems, heavy stocking rates of the latter two can cause extreme degradation (Fynn *et al*, 2003).

In both CANs, grazing can be used effectively as a management tool to maintain the Sourveld grassland condition and sustain an oribi-favourable grassland species composition. This can be achieved by: not exceeding the livestock stocking rate or carrying capacity of the veld, dividing different veld type units with oribi-friendly fences to prevent area-selective grazing and to allow the veld to rest regularly but depending on the grazing system (Ezemvelo KZN Wildlife, 2008). Oribi show a positive selection for areas that have been mowed less than six months earlier and burnt less than twelve months previously.

Tainton, (1981) and Rowe-Rowe (1982a) agree that without a form of defoliation in both the CANs, the species composition of the grassland will change as palatable grasses e.g. *T. triandra* decrease and unpalatable grasses increase. To limit the change in species composition and provide the oribi with productive grazing in the Sourveld grassland, it is recommend that principal mowing practices and burning practices should be adhered to.

- Mowing should not take place when soil moisture is sufficient enough to lead to soil compaction.
- Sourveld grasslands should not be mowed lower than 8cm to 10cm
- An entire grassland block should not be mowed completely in one season
- Mowed areas (excluding areas dominated by *Pennisetum clandestinum*) should alternate yearly with burning
- Areas subjected to burning and mowing in successive years should be left to rest in the third year.
- Mowing should be done in Feb/early March to allow for a green flush of grass for winter food for oribi. (After: Ezemvelo KZN Wildlife, 2008)

The successful implementation of oribi-specific mowing and burning procedures will expose the vegetation material with a higher crude protein amongst the dry grass (Oliver *et al.,* 1978) thereby providing the oribi with a higher quality food source.

5.6 Suitability Modeling

The modeling technique used in this project has demonstrated the effectiveness of GIS in habitat suitability modeling. A GIS centred habitat suitability analysis technique has not been undertaken on the oribi populations in KwaZulu-Natal and is therefore a field of study that requires further investigation. New insights into species habitat relationship patterns have been derived from these proven GIS techniques regarding oribi distribution. Realism accuracy and the effectiveness of the depiction of important habitat factors need to be considered if this model is to be used constructively. This model can be considered coarse in terms of other habitat suitability models but the overall accuracy of the model was 63.64% and shows the effective nature of the techniques used. Due to the paucity of current, up-to-date land cover data sets, the temporal accuracy of the model is not ideal but the techniques have formed a basis for further modeling. The future mapping of suitable oribi habitat will be a matter of acquiring up-to-date data. A project of this nature is predominantly hinged on the quality of data available to the model and it is for this reason further research must be undertaken in an effort to limit the margin of error when dealing with red data species. KwaZulu-Natal is experiencing rapid infrastructural and population growth, placing further stress on natural resources integral for oribi survival and the onus is on projects similar to this to stress the importance of natural resource conservation in lessening the impact of infrastructural development on our natural resources. Techniques used in this project could be transposed into other projects utilising GIS as the primary tool of investigation. This will become increasingly more pertinent when our natural resources become exploited to a level where regeneration is unsustainable, as is the case with the oribi.

This assessment is intended to provide information for the development of conservation strategies, to contribute to future field survey efforts, and to help identify management priorities zones. These analyses were conducted by using regional-scale spatial data sets that are effective for evaluating broad-scale patterns but should not be expected to provide precise information for specific locations on the ground. This analysis provides measures for comparing estimated landscape permeability between different areas; however, the actual functionality of the linkages identified remains to be demonstrated through field surveys and additional research.

Chapter Six
Conclusion and Recommendations

6.1 Conclusion

The aim of this project was to develop GIS-based habitat suitability maps and suitable habitat linkages for oribi using several environmental variables identified in Everett's (1991) work and this GIS investigation.

6.1.1 Objectives of the Study Reviewed

- To statistically establish environmental factors that best explain oribi distribution;
- To create oribi habitat suitability maps based on the environmental factors obtained in the previous objective;
- Create an oribi Conservation Area Network (CAN) through cost distance functions and algebraic expressions;
- To identify, using cost distance analysis, suitable habitat linkages between fragmented oribi populations in the oribi CANs identified in the previous objective;
- Draft land management recommendations for two suitable habitat linkages identified in the above analysis.

The objectives were completed through the identification of environmental factors that were indicative of oribi distribution in the study area through a statistical multivariate and univariate analysis. The environmental variables employed were in the following categories: food preferences, habitat preferences, and physical site characteristics. An Analytical Hierarchy Principle analysis using expert knowledge provided the basis to rank each variable and thereby create an oribi habitat suitability map based on the relative importance of the identified variables. An oribi Conservation Area Network was then created using cost distance functions and algebraic expressions. The identified oribi CAN provided the foundation to identify suitable habitat linkages between fragmented oribi populations through cost distance analysis techniques within the CAN. Following the identification of the suitable habitat linkages, land management recommendations particular to oribi were drafted for two of the linkage zones.

The research project thus described the habitat characteristics of the oribi, identified a Conservation Area Network with specific linkages particular to oribi and finally provided management recommendations for two of the linkage zones.

6.2 Recommendations

The flow of information emanating from data collected in the field, to a point where informed recommendations can be formalised, is a step-by-step process where each step needs to be completed in order to complete the following task. ***Figure 3.6*** visually presents the structure and framework evident in this project. A research framework should never be a detached circuit, impartial and separate from external concepts. This project takes cognisance of this and continues the thought process into practical recommendations that are feasible and achievable when directly compared to previous habitat suitability studies reviewed in ***Chapter 2***. The steps identified in the lower text boxes of ***Figure 3.6*** are integral to the practical implementation of these recommendations, and could provide further model refinement for future corridor references.

The identified corridors in each oribi CAN should undergo a corridor effectiveness and connectivity analysis. The design of each linkage corridors and the management of the adjoining landscape for viable animal movement in a manner that is effective for oribi sub population connectivity will rely heavily on the connectivity analysis. This analysis will take into account the current land use and ownership through a series of specialist field-based visits and Surveyor General subdivision enquiries. The effectiveness of each corridor will require analyses based on factors other than those identified in this project. Land Redistribution, Restitution and Tenure, under the land reform programme, implemented by the South African Department of Land Affairs, must be considered when adjudging the effectiveness of a proposed corridor. The forementioned gazetted processes could lead to current land use changes, thereby affecting long term planning of any suitable oribi habitat. Other factors to consider are the landowners' conservation interests and planned future infrastructure developments within any proposed corridor zone. This information will be difficult to acquire without landowner interviews and surveys but will be vital in improving the project's effectiveness.

Information on future spatial planning coupled with a proactive and effective land management structure which maintains options for directing human development and managing habitat will be equally important for maintaining or improving oribi linkages at a local CAN scale. The details of this may be disseminated through scientific literature and popular literature articles published under the auspices of the relevant NGO working groups and conservation authorities. Education and relevant information dissemination can be achieved at every level of the national syllabus. A programme could predominantly be based on an outreach system where learners will be made aware of the inherent need to conserve the grassland and its related biota. Across South Africa, syllabi could be adapted so to raise the profile and emphasise the plight of any endangered biota relative to that region. Any form of public education and the subsequent public advocacy will add momentum to future formalised legislation on wildlife corridors for endangered species. The maintenance and enhancement of such corridors may become a mandatory requirement for landowners whose land falls within suitable oribi habitat. Monitoring the corridors will be achieved by instilling an ongoing land use audit. This will work twofold; firstly, one could ascertain the efficacy of the delineated corridors on oribi movement and secondly, gaps, sinks and obstacles could be identified for further model refinement.

By implementing a list of mandatory preservation requirements, spatial planners could maintain and reinstate broken or disjointed habitat linkages. Particularly, this would take into consideration a proposed limiting on the construction of impermeable barriers to oribi within these zones. This should greatly improve the antelope's mobility between islands of suitable habitat through making use of such linkages.

Oribi make use of a variety of grassland habitats but are considered selective feeders. This must be considered when viewing the habitat suitability map and the thoughts of reintroduction of oribi onto land considered medium low to low. Oribi prefer north to north easterly facing slopes that are gently sloped but avoid lowland that is almost flat. Oribi avoid plantations and heavily cultivated lands such as sugar cane and intensive monoculture but do prefer open grassland. This is particularly worrying when considering the dwindling extent of KwaZulu-Natal's untransformed grasslands. The extent of suitable habitat fragmentation is augmented by further degradation and mismanagement of grasslands by uninformed or negligent landowners. Oribi can be considered an indicator species in terms of grassland health and habitat degradation. It is therefore important to realise that oribi disappearance is a precursor to further degradation and destruction. The merit and speed of data dissemination of GIS in natural resource management is particularly highlighted when we consider the rate at which grassland areas in KwaZulu-Natal are being transformed. At this current transformation rate temporal data accuracy considerations must be highlighted. As data becomes available it will be necessary to update the model with current NLC, KZN vegetation and oribi GPS data layers for greater prediction accuracy. It is important to realise that with the use of GIS, data dissemination could be faster and the issue of habitat transformation can reach the general public before further damage is done. Public awareness must play a pivotal role in the conservation of an endangered species, primarily though visual interpretation. A model similar to the one created by the habitat suitability model is an ideal way in which the layman can quickly grasp the extent of oribi habitat past, present and future. The combination of the suitability model coupled with the farm-specific maps of the linkages and oribi CANs go hand in hand to provide an overarching view for decision makers and planners.

As the majority of the oribi in KwaZulu-Natal occur on privately owned land, it is also imperative that these maps and information can reach the landowners whose grasslands are considered highly suitable. This could be done through a logistical process of overlaying the cadastral dataset, identifying integral parcels of land and then contacting the relevant landowners whose details reside in the EKZNW Oribi GeoDatabase (ESRI, 2005).

A viable vehicle for the dissemination of the above-mentioned information is the OWG annual report-back meeting. This yearly meeting is held at centralised venues throughout oribi habitat and aims to reach the individuals who are critical for oribi survival. It is here where landowners, managers and conservation authorities are invited to share information relevant to oribi and ensure the animal’s survival into the future. An array of oribi specialists are invited to present findings, discuss management recommendations and largely interact with the most pivotal individuals in oribi conservation - the landowners and managers. Initiatives such as these go hand-in-hand with other grassroots programmes to bring the plight of the diminishing grasslands into the public eye, simultaneously raising public awareness and fomalising a better understanding of the role grasslands play in conservation.

Further oribi suitability analysis could be undertaken through the process of Ecological Niche Modeling (ENM) as in the work published by Hirzel et al (2002). ENM uses principles based on the maximum-entropy approach for species habitat modeling, thereby facilitating a forecasting mechanism for future habitat predications. As with any future research ENM will provide another facet to the ever-growing knowledge base thereby ultimately improving our understanding of this antelope.

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Appendix A: The Analytical Hierarchy Process

Numerous decision making techniques attempt to determine the relative importance, or weight, of the objectives (alternatives) in terms of each criterion involved in a given multi-criteria decision making problem. The AHP method is, according to Malczewski (1999:217-18), based on three principles: 1) decomposition 2) comparative judgment, and 3) synthesis of priorities. First, the AHP decomposes a complex MCDM system of hierarchies that captures the essential elements of the problem. The principle of comparative judgment requires assessment of pair-wise comparisons of the elements within a given level of the hierarchical structure, with respect to their parent in the next higher level. The synthesis of the priorities principle takes each of the derived ratio-scale local priorities in the various levels of the hierarchy and constructs a composite (global) set of priorities for the elements at the lowest level of the hierarchy, i.e. alternatives. Where comparative judgment is of concern, psychological experiments (Miller, 1965) have shown that the average individual cannot simultaneously compare more than seven objects (plus or minus two). Therefore, the linear scale required to quantify pair-wise comparisons as proposed by Saaty (1980) are defined on the interval [9, 1/9], thus the available values for the pair-wise comparisons are members of the set: {9,8,7,6,5,4,3,2,1,1/2,1/3,1/4,1/5,1/6,1/7,1/8,1/9}. The intensity of the importance is reflected by these values, where 9 would imply absolute importance and decreasing downwards to equal importance (1). The highest value implies that the evidence favouring one activity over another is of the highest possible affirmation as opposed to two activities contributing equally to the objective. The reciprocals imply that if activity *i* has one of the above nonzero numbers assigned to it when compared to activity *j*, then j has the reciprocal value when compared with i.

After decomposition, the AHP involves the processing of pair-wise comparisons to ultimately return the implied relative weight of importance of the compared items. To achieve the last part of the process Saaty's method makes use of eigenvalue theory. It deals with the structure of an *m x n* matrix (where *m* is the number of alternatives and *n* is the number of criteria). The decision matrix is constructed by using the relative importance of the alternatives in terms of each criterion. The vector (a_{i1}, a_{i2}, a_{i3} …, a_{in}) for each *i* is the principal eigenvector of a *n x n* reciprocal matrix which is determined by pair-wise comparisons of the impact of the *m* alternatives of the *i*-th criterion. The entry a_{ij} represents the relative value of alternative A*i* when considering it in terms of a particular criterion. Thus according to Maczewski (1999:10), where w*j* is the weight of importance of the *j*-th criterion, the best alternative in the AHP maximisation case is indicated by the following:

$$A_{AHP\text{-}score} = \max_i \sum_{j-1}^{n} a_{ij} w_j, \quad for\ i = 1,2,3\ldots,m$$

To determine the degree of consistency in the pair-wise comparisons, the consistency ratio (CR), which involves the maximum right eigenvalue, is also produced. Saaty indicated that matrices with CR ratings greater than 0.10 should be re-evaluated.

Criticism of the AHP includes 'the rank reversal problem' (Belton & Gear 1983), problems with the pair-wise comparisons and the 1-to-9 scale (Lootsma 1990; Goodwin & Wright 1998; Leskinen & Kangas 1998), and it being cumbersome and time-consuming (Steward *et al.,* 1997). More recently, Leskinen, Kangas & Kangas (2003) argued that, in general, pair-wise comparisons data into ratio scale is more informative in MCDM than ordinal assessments. The cost in terms of time for the procedure to reach judgment could be high. Moreover, the increased amount of work can have negative impacts on the accuracy of ratio scale judgments. This demonstrates that various theoretical and empirical results indicate that there is no single scale which can always be classified the "best" scale or the "worst" scale for all cases.

During the oribi population and habitat viability assessment (PHVA) workshop held in June 2006, a series of comparative judgment decisions were outlined. These decisions were based on the experience of 36 individuals with expertise in the ecology and conservation of the oribi. It was through this workshop that the decision matrix was enumerated through a series of pair-wise comparisons using a linear 9-point continuous scale.

Appendix B: NLC Land Cover Classification System

The NLC classification system provides reliable land cover data at medium to large scales. The National Land Cover (2000) Project was jointly coordinated by Council for Scientific and Industrial Research (CSIR) and Agricultural Research Council (ARC). The objective was to produce an up-to-date digital raster (30 pixel size) land-cover map for South Africa, Swaziland and Lesotho. The map extends for 10km into neighbouring Mozambique, Zimbabwe, Botswana and Namibia. The minimum mapping unit (MMU) size is 1 ha. The NLC 2000 classification scheme definitions and legend have been standardised at all times to ensure mapping consistency.

Tabulated below is the level I land cover classes mapped throughout South Africa

Code	Level 1 land-cover class
1	Forest and woodland (savanna)
2	Indigenous forest
3	Thicket, bushland, bush clumps, high fynbos
4	Low shrubland and fynbos
5	Herbland
6	Unimproved grassland
7	Improved grassland (pasture, recreation fields)
8	Forest plantations (exotic tree spp.)
9	Waterbodies
10	Wetlands
11	Bare rock and soil (natural)
12	Bare rock and soil (erosion surfaces)
13-17	Degraded vegetation, by classes 1,2,3,4,5,6
18-23	Cultivated lands, variations of permanent/temporary crops, irrigated/drylands and commercial/subsistence/sugarcane
24	Urban/built-up land (residential)
25-28	Urban/built-up land (residential small holdings by subdivided vegetation classes 1,2,3,4,5,6)
29	Urban/built-up land (commercial)
30	Urban built-up land (industrial and transport)
31	Mines and quarries

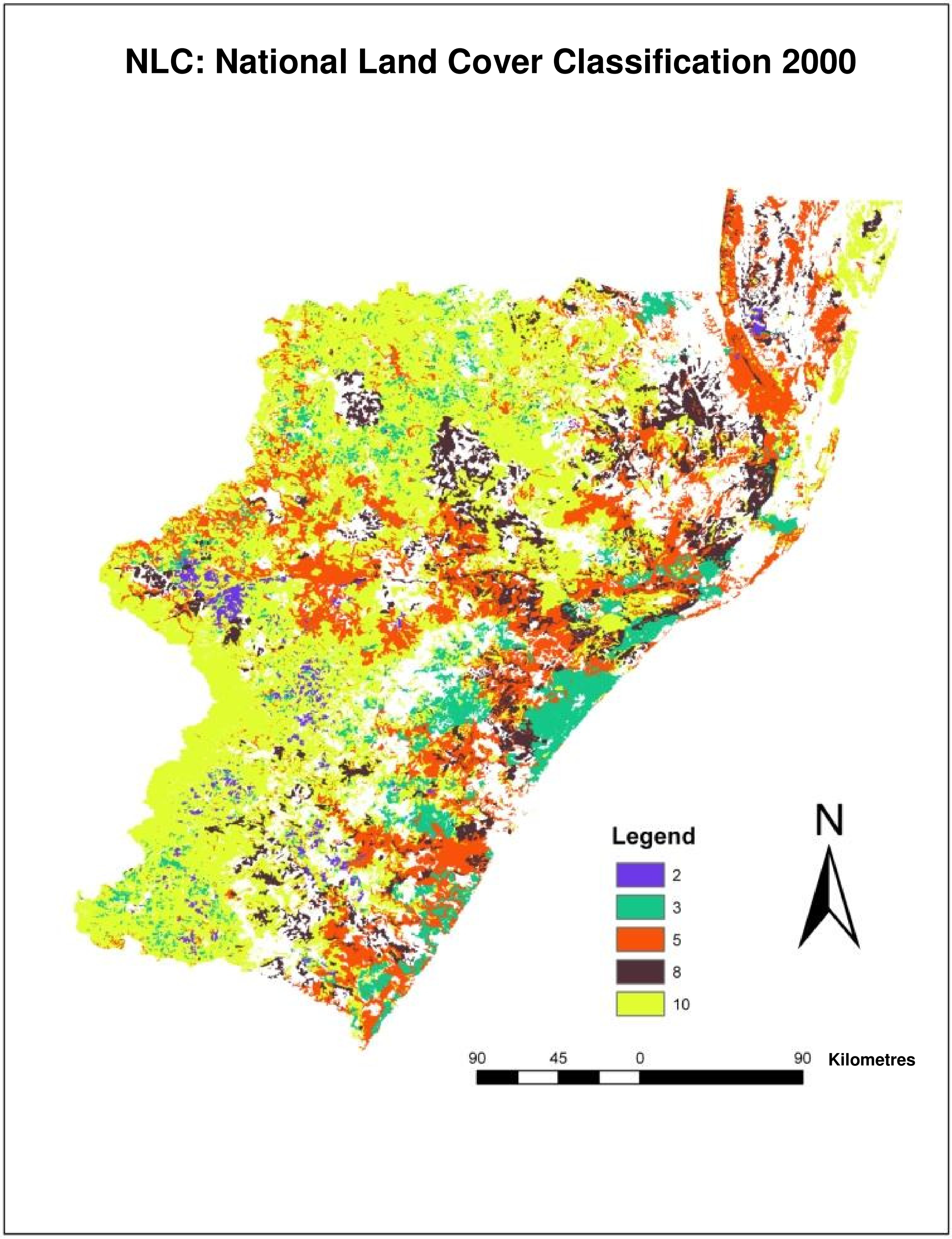

Figure A National Land Cover Classification

AppendixC

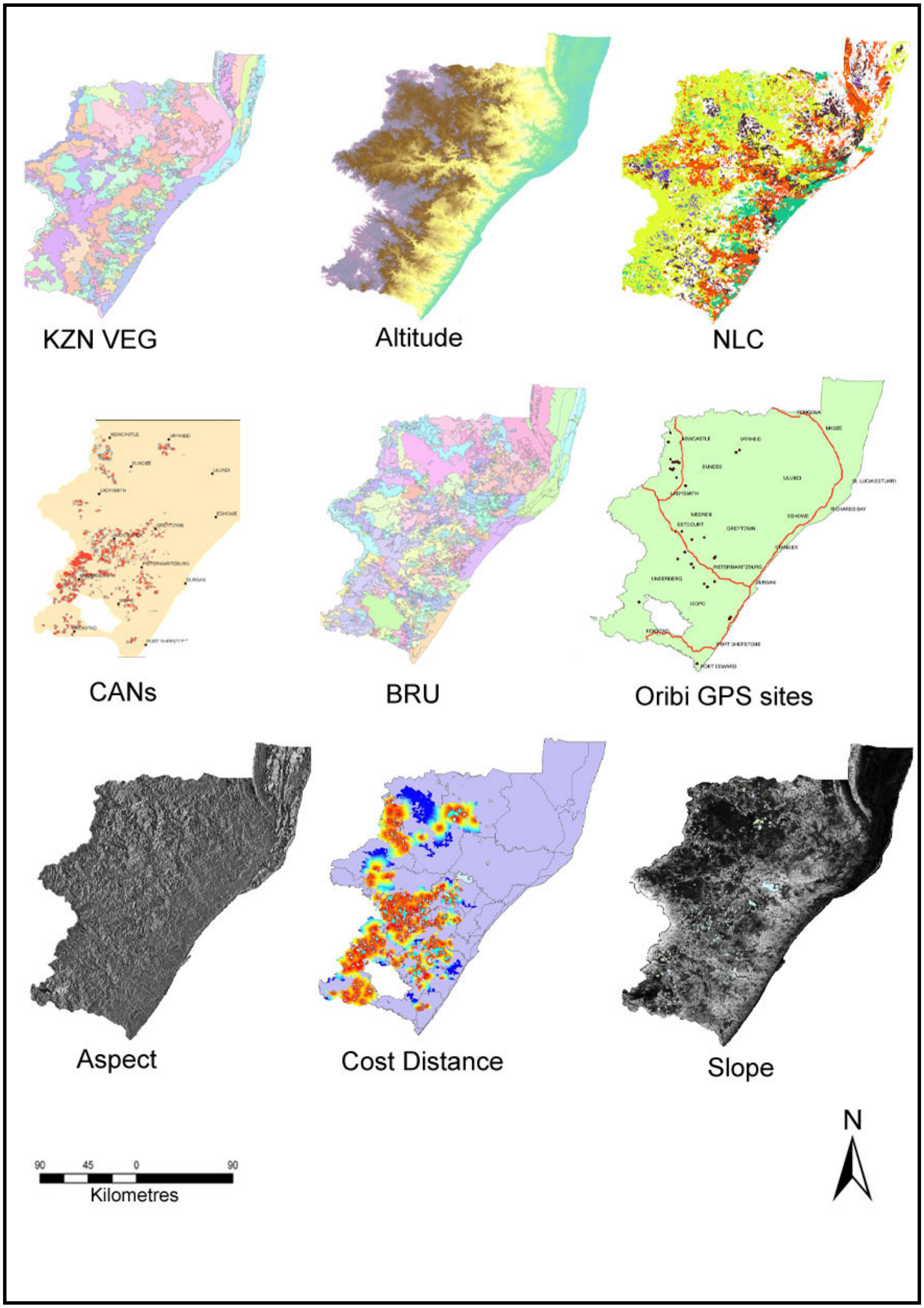

Figure B Selection of layers as derived from various factors