# BREEDING HABITAT OF BLUE CRANE (*ANTHROPOIDES PARADISEUS*) IN MPUMALANGA PROVINCE, SOUTH AFRICA

by

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# DECLARATION

I declare that the dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Zoology has not previously been submitted by me for a degree at this or any other university; that it is my own work in design and execution, and that all material contained herein has been duly acknowledged.

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[redacted] [redacted]

16/09/2009
**Date**

# DEDICATION

This study is dedicated to my family, especially my mother; her sacrifice and patience made this endeavour possible.

# ABSTRACT

The aim of this study was to determine the breeding habitat of Blue Crane (*Anthropoides paradiseus*) by investigating the home range, habitat selection and habitat suitability. Geographic Information System (GIS) was used as the main tool for analysis.

Home range sizes of Blue Cranes were studied during the breeding season using direct observation method. A 50% and 95% Adaptive Kernel was used to estimate home range sizes. The home range sizes were 9.0 ha and 43.5 ha for 50% and 95% Adaptive Kernel, respectively. All the nests were located within 50% Adaptive Kernel, often referred to as core area. The nests were located in agricultural land (mainly pasture) and close to water sources.

Habitat selection was studied at nest sites (n = 74) and random sites (n = 200) following site attribute design. The Blue Crane showed a preference to breed in agricultural lands, close proximity to water sources, higher elevation areas, within north eastern sandy highveld vegetation, and north facing slope. The Blue Crane also avoided anthropogenic factors such as built-up land, roads and railway line.

ModelBuilder extension of ArcGIS software was used to construct a breeding habitat suitability model for Blue Cranes. Nine habitat variables (water source, slope, aspect, elevation, land use, vegetation, built-up land, roads and railway line) were used in the model. The model was constructed using reclassify and weighted overlay command. Highly suitable sites accounted for 601, 448 ha, while moderately suitable sites accounted for 823, 593 ha, and least suitable sites accounted for 3, 000, 153 ha.

This study demonstrated the effective use of GIS technology in analysing the breeding ecology of Blue Crane. The GIS technology provided capabilities for capturing and analysing varied and large data. It was also evident that availability of accurate and complete species data remains vital to enable the full utilization of the GIS technology.

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# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

The Blue Crane (*Anthropoides paradiseus;* Lichtenstein, 1793*)* is endemic to southern Africa. It is the world's most range-restricted crane (Hockey *et al*., 2005) with most of its populations occurring in South Africa (Barnes, 2000). The Blue Crane, which is also the national bird of South Africa, has experienced a population decline of more than 80% in the grassland biome, where it was previously abundant (Le Roux, 2002). The total population is estimated at 21 000 individuals (McCann *et al*., 2001). South Africa is home to approximately 95% individuals (Barnes, 2000). The decline of this species is mainly associated with factors such as habitat loss (Vernon *et al*., 1992) and a variety of other anthropogenic factors such as poisoning (Allan, 1994), and economic developments (Bidwell, 2004). Consequently, this species is listed as vulnerable in the ESKOM Red Data Book of Birds of South Africa, Lesotho and Swaziland (Barnes, 2000).

## 1.2 THE CRANE FAMILY

There are 15 species of cranes, distributed worldwide (International Crane Foundation, 2001). Southern Africa is home to the Blue Crane, Grey Crowned Crane (*Balearica regulorum;* Bennett, 1833), and Wattled Crane (*Bugeranus carunculatus;* Gmelin, 1789).

Cranes are large, long-legged and long-necked birds (Walkinshaw, 1973) of the Order Gruiformes and, Family Gruidae. They range in height from 90 to over 150 cm; the Demoiselle Crane (*Anthropoides virgo;* Linnaeus, 1758) being the smallest and Sarus Crane (*Grus antigone;* Linnaeus, 1758) the tallest member of the species (Archibald and Lewis, 1996). The bills of cranes are elongated and tapered, and are often longer than their heads (Meine and Archibald, 1996). Most cranes are naked on the upper half of their heads. All crane species, except the Blue Crane and Demoiselle Crane have red plumage on their heads (Schoff, 1991).

The crane family is divided into two subfamilies: the Crowned Cranes (*Balearicinae*) and the Typical Cranes (*Gruinae*) (Ellis *et al*., 1996). Crowned Cranes are distinguished from the Typical Cranes by their lack of a coiled trachea, a loose body plumage, and an inability to withstand severe cold (Archibald, 1976). Crowned Cranes retain the ability to roost in trees and are the only cranes able to do so (Meine and Archibald, 1996). All crane species are dependent on wetland habitat, except for the Blue Crane and Demoiselle Crane, both of which have a greater affinity for grasslands (Meine and Archibald, 1996).

As mentioned above, the crane family is divided into two subfamilies. Below is a list of various members that make up these two subfamilies.

Subfamily – Crowned Cranes (*Balearicinae*)

- Genus (*Balearica*)
    - Black Crowned Crane (*Balearica pavonina;* Linnaeus, 1758)
    - Grey Crowned Crane (*Balearica regulorum;* Bennett, 1833)

Subfamily – Typical Cranes (*Gruinae*)

- Genus (*Grus*)
    - Brolga Crane (*Grus rubicundus;* Perry, 1810)
    - Eurasian Crane (*Grus grus;* Linnaeus, 1758)
    - Sandhill Crane (*Grus canadensis;* Linnaeus, 1758)
    - Whooping Crane (*Grus americana;* Linnaeus, 1758)
    - Sarus Crane (*Grus antigone;* Linnaeus, 1758)
    - Siberian Crane (*Grus leucogeranus;* Pallas, 1773)
    - White-naped Crane (*Grus vipio;* Pallas, 1811)
    - Hooded Crane (*Grus monacha;* Temminck, 1835)
    - Black-necked Crane (*Grus nigricollis;* Przevalski, 1876)
    - Red-crowned Crane (*Grus japonensis;* Muller, 1776)
- Genus (*Anthropoides*)
    - Blue Crane (*Anthropoides paradiseus;* Lichtenstein, 1793)
    - Demoiselle Crane (*Anthropoides virgo;* Linnaeus, 1758)

- Genus (*Bugeranus*)
    - Wattled Crane (*Bugeranus carunculatus;* Gmelin, 1789)

## 1.3 DESCRIPTION OF THE BLUE CRANE

The Blue Crane is a large terrestrial bird that is approximately 107-150 cm tall (Newman, 1983). This bird can easily be distinguished from other cranes by its uniform grey plumage and secondary feathers of the wing that are often mistaken for a tail; short pinkish yellow bill, brown eyes and a head that looks rather swollen (Urban *et al*., 1986). Juveniles are a lighter shade of blue grey than adults and lack the long wing plumes; the crown of the head is also pale chestnut. The males and females are virtually indistinguishable (Meine and Archibald, 1996). This species feed on grains, green shoots, small reptiles, seeds, and insects (Maclean, 1993). This bird is known for a loud, rattling and a very distinctive croak, usually in the form of a duet (Newman, 1983).

## 1.4 THE BREEDING ECOLOGY OF BLUE CRANE

Blue Cranes are monogamous, just like other crane species, and mated pairs usually stay together until one dies (Meine and Archibald, 1996). However, a monogamous pair bond is only formed once a pair has had a successful breeding (Tacha *et al*., 1992).

The breeding season stretches from the time nests are built during September to when the chicks are fledged in May (Shaw and Hudson, 2001). During the breeding season the distribution is rather dispersed, as the flocks break up and form pairs (McCann, 2000). The mature birds are often seen in pairs while the immature birds often flock together (Urban *et al*., 1986). Two birds, a male and a female, engage in a courtship dance that ends when the excited birds stop in duet, called unison call, which has a sexual function (Hockey *et al*., 2005).

Breeding pairs require little effort when building a nest. Territories are claimed in open areas, with good view so that predators can easily be detected from a distance (Barnes, 2000). This birds breed predominantly in dry grassland areas or in pasture and stubble fields across their geographical range (Allan, 1993). A clutch of two dark brown eggs are laid on the ground (Barnes, 2000), and generally in areas which have thick and fairly short vegetation (McCann, 2000). Alternatively, they nest in shallow wetlands (Walkinshaw, 1973). These birds have shown a level of dependence on water during breeding as nests are often located close to water sources (McCann *et al*., 2001).

The male and female take turns in incubating the eggs until they are hatched (McCann *et al*., 2001). Once chicks have hatched, both parents feed the chicks with insects and plants for about 15 days (Walkinshaw, 1973). When chicks are stronger, they follow their parents to learn to forage and fly (Meine and Archibald, 1996).

### 1.5 THE DISTRIBUTION OF THE BLUE CRANE

This species has the most restricted range of all crane species (Meine and Archibald, 1996). Its populations are distributed in southern Africa, with most of it occurring in South Africa (Barnes, 2000). Historically, this species was abundant in short, dry grasslands and upland areas of southern Africa, with smaller populations in Namibia centred at the Etosha Pan (Allan, 1997). In Botswana, it is found towards the extreme south-east but with no confirmed breeding records (Allan, 1997). In Lesotho, it occurs as a non-breeding summer migrant (Meine and Archibald, 1996). This species has not been recorded in Swaziland since 1995 (Hockey *et al.,* 2005).

In South Africa, there are three sub-populations of Blue Cranes (McCann *et al*., 2001). The first population occurs in the central Karoo within the Northern and Eastern Cape Provincial boundaries. The second population is centred at the junction of Mpumalanga, Free State and KwaZulu-Natal. The third population occurs in the fynbos biome of the Western Cape Province. This third population adapted well to the agricultural wheat belts of the Swartland and Overberg regions of the southern Western Cape (Barnes, 2000). The Swartland-Overberg population forms the largest core population of about 10 650 individuals, which is approximately 50% of the total population (Barnes, 2000).

### 1.6 THREATS FACING BLUE CRANE POPULATIONS

There are various factors that are contributing to the decline in the population number of Blue Cranes. In the grassland biome, it is affected mainly by habitat loss and commercial afforestation

(Tarboton, 1992). In most cases, grasslands have been converted to pine and eucalyptus plantations for the production of pulp and timber (Allan, 1997). Such practice deprives this species of the dry open conditions it require, especially for breeding.

Anthropogenic factors remain the most threatening effects on wildlife and conservation (Moore *et al*., 2008). Exacerbating incidences of intensive livestock grazing, and expansion of agricultural activities continues to pose threats to the habitat of Blue Cranes (Allan, 1993). An anthropogenic factor has played a major role in the decline of Blue Crane population in several areas especially in the grassland biome (Allan, 1994).

The documented decline of this species within the grassland portions of its range has also coincided with numerous reports of poisoning (Tarboton, 1992; Vernon *et al*., 1992; Hockey *et al.,* 2005). Poisoning often occurs in three ways (Johnson, 1992). Firstly, it can be intentional, with the aim of killing the birds. Secondly, it can be inadvertent and aimed at killing other species that cause crop damage. Thirdly, it can occur during the application of pesticides to crop fields (Allan, 1994). Johnson (1992) discovered approximately 600 Blue Cranes that were killed from poisoning in a single event.

The population in the Karoo is reported as stable although power line collisions are still a significant threat (Kotoane, 2003). The development of agriculture in the Karoo as a consequence of the construction of the Orange-Fish River canal may pose a long-term threat to the population in the northeastern Cape Province by increasing the level of crop predation and subsequent poisoning (Allan, 1994). Also, in the Overberg and Swartland, power line collisions pose some threats even though the population is increasing (Shaw and Hudson, 2001).

## 1.7 FUNDAMENTALS OF GEOGRAPHIC INFORMATION SYSTEM

Geographic Information System (GIS) is a computer system for the capturing, storing, visualising, managing, and manipulation of spatially referenced data (Pullar, 1997). The GIS technology is characterised by its ability to handle spatial data sets in such a manner that it ties objects to their specific location (Fischer *et al*., 1996). This functionality allows users to depict relationships between objects and their environment. This technology is also referred to as a spatial decision support system (Heywood *et al*., 2002). Spatial data which is information about location is the core of GIS, and it is often accompanied by attribute data (Burrough, 1986). A combination of spatial and non spatial data enables GIS to be an effective and powerful tool (Clarke, 2001).

There are a number of elements that are essential for effective GIS operation. According to Burrough (1986), these include:

- The presence of a processor with sufficient capacity to run the software and extensions.
- Sufficient memory for the storage of large volumes of data.
- A good quality, high resolution colour graphics screen.
- Data input and output devices (Global Positioning System (GPS), digitizer, scanner, and plotter).

As an abstraction of real world phenomena, geographic data can only provide a best guess at the location, geometry and attribute characteristics of the entities that it represents (Shabani, 2006). The numerous factors that contribute to this approximation can vary greatly from one digitally mapped product to another. As a result, when comparing one set of data to another in a geographic information environment, the analyst must be aware of those contributing factors that have defined and shaped the abstractions. This technology assist scientists and decision makers in integrating diverse data, establishing estimates of costs, determining decision impacts, and building land use and ecological scenarios (Shabani, 2006).

One of the advantages of this technology is its ability to handle different layers of map information relating to an area (Burrough, 1986). Each layer normally describes a different aspect of its geography, for example a layer may contain the geology of an area, while another may contain the vegetation of the same area. Subsequent layers might include land cover data, species distributions, or the socio-economic characteristics of the human population. Thus, a combination of various layers may be used to solve a particular problem. Furthermore, as problems change, the data can be processed in different ways to address new issues in a highly flexible way especially using spatial models (Heywood *et al*., 2002).

There are a number of issues that should be recognised and addressed before proceeding with GIS analysis (Heit *et al*., 1996).

- Ensuring that there is an understanding of different data formats.
- Gathering data that is relevant to the objectives of the project.
- Handling data collected at different time frame.
- Understanding the implications of using data available in different datum.
- Understanding the kind of tools needed to carry out appropriate analysis.

Given that the time required to sufficiently address the above mentioned issues is often underestimated, it should be noted that the required final product may never be delivered in a suitable and complete form (Shabani, 2006). It is therefore important to address these issues at the start of any GIS project.

Metadata forms an integral part of spatial data. Metadata is defined as descriptive information about data; it is used to assess data quality (Lanter, 1994). Metadata are often conveyed in the form of a data dictionary which conveys the meaning and structure of entity and attribute data (Aronoff, 1989). This dictionary specify the type and range of values each attribute may take and defines the meaning of attribute value codes, gives units of measurement (if appropriate), defines the meaning of entity and attribute labels, identify an authority, for each definition, and describes the layout and forms of records in the attributes database.

Johnston (1998) caution that GIS users should not take GIS products (i.e., maps, models) as accurate renditions of reality without questioning their derivation. The adage “garbage in, garbage out” is as applicable to the field of GIS as it is for any computer based tool. Just as an understanding of the methods and data sources used in a scientific experiment is crucial to evaluating results, the methods and source information used to construct maps and models are crucial when evaluating the outputs.

## 1.8 THE USE OF GIS IN WILDLIFE CONSERVATION

Recently, there has been an increase in wildlife and habitat information for some species (Vogiatzakis, 2003), and the development of tools for managing information (Shabani, 2006).

Information needs for biodiversity are many and varied. Therefore, systems that holds biodiversity information needs to be spatially explicit, to allow for the opportunity to predict where new populations of endangered species with a limited known range might be expected, thereby indicating potential conservation hot spots (Vogiatzakis, 2003). The GIS technology is an important tool for monitoring biodiversity because of its ability to hold and manage large varieties of spatial and non spatial data (Dettmers and Bart, 1999).

In the past, GIS was mainly used for descriptive purposes and for producing maps showing species geographic locations (Johnston, 1998). That trend has changed in recent years with a growing number of studies (Pereira and Itami, 1991; Sodhi and Oliphant, 1992; McShea *et al*., 1995; Howell and Chapman, 1997; Perrin and Carranza, 2000; Gurnell *et al*., 2002; Buchanan *et al*., 2003), using this technology for analytical purposes.

The use of this technology in wildlife conservation has enabled researchers to organize information gathered across broad geographic regions in a spatial database and perform analysis at a scale that was previously difficult to achieve (Miller, 2000). For example, this technology has been used in habitat suitability studies (Dettmers and Bart, 1999; Lauver *et al*., 2002; Downs *et al*., 2008). Habitat suitability models have proven to be useful in predicting habitat quality for species that are endangered, threatened or vulnerable (Gerrard *et al*., 2001). Identification of suitable habitats for numerous bird species shows a growing trend towards the use of GIS-based modelling procedures (Dettmers and Bart, 1999). However, Gurnell *et al*. (2002) noted that the application of GIS in wildlife management and conservation is still hampered by the lack of reliable and complete data on certain species.

Researchers in wildlife conservation have also taken advantage of using various data collection techniques (Johnston, 1998). Remote Sensing from aircraft and satellites has allowed researchers to collect data at scales that include many interacting ecosystems and even whole biomes (Gonzalez and Wintz, 1977). Remote Sensing is defined as the science of acquiring, processing, and interpreting images and related data obtained from aircraft and spacecraft, which record the interaction between matter and electromagnetic energy (Clarke, 2001). Remote Sensing is an important source of spatial data because it has the ability to collect information even in areas that are inaccessibility mainly due to the distance and terrains (Davis *et al*., 1991).

Another data collection tool that has proven useful in wildlife conservation is a GPS (Johnston, 1998). GPS is a satellite based radio navigation system that provides three dimensional positions (Seeber, 2003). With a GPS, a user can automatically determine the location (latitude and longitude) at any point on earth with the accuracy level ranging from few centimetres to metres. GPS tracking devices has been used in conservation for tracking of wildlife movement (Moen *et al*., 1996). One of the advantages of using GPS tracking devices is that it can track species over any distance, under all weather conditions and in areas that are not easily accessible (Vogiatzakis, 2003).

## 1.9 SPECIES HOME RANGE ANALYSIS

Animals limit their activity to a particular area, within which they find the resources necessary for safety, foraging, and reproduction. Such an area, regularly used by an individual during a specific period of its life, is defined as a home range (Burt, 1943). Usually, home ranges comprise heterogeneous areas determined by physical and biological factors (Burt, 1943). Home range studies of various species show that for a number of environmentally related reasons, certain portions within the home range are used more frequently than others (Konecny, 1989). The area of the most intensive use has been conceived as the core area of the home range (Burt, 1943), and may be related to a greater availability of resources for food and safety (Samuel and Garton, 1987).

Home range sizes are studied by observing species movement and recording fixes at each location visited. In many instances, the point data, often referred to as "fixes", are determined by telemetry (Burt, 1943). Fixes are normally used to test a basic hypothesis concerning animal behaviour, resource use, population distribution, or interactions among individuals and populations. Researchers are rarely interested in every point that is visited, or the entire area used by an animal during its lifetime. Instead, the focus is normally on home range (Okubo, 1980).

Estimating home range area remains valuable; however, some knowledge of the relative intensity of use of a home range can help to identify the location of resources important for an animal (Hayne, 1949). The integration of home range and habitat use are necessary to understand the resource distribution and selection by various species (Yates *et al.,* 2002).

With the advancement of radio tracking techniques, there has been an increase in the quantity and quality of fixes obtained for a variety of wildlife species (Kenward, 1992). Automated tracking systems, in particular, produce enormous amounts of data that can be effectively handled only by some form of computer processing. The data collected from these tracking systems is often used to determine daily movements, large scale movements, home ranges, and habitat use by individuals and populations (Erickson *et al*., 2001).

There are various home range software packages such as CALHOME, HOME RANGE, RANGES IV, RANGES V, and TRACKER. It should be noted that comparing home ranges of animals among different research studies can be misleading unless researchers report the software package used, with which home range estimators have been calculated, user selected options for calculating each estimator noted, and the input values of required parameters given (White and Garrott, 1990; Laver and Kelly, 2008). The home range software packages contain different estimators such as Kernel, Minimum convex polygon, and Harmonic mean home range. Each of these estimators has different advantages and disadvantages. Just as it is the case with choosing home range software; it is also important to use similar estimators for comparisons between studies (White and Garrott, 1990). Laver and Kelly (2008) caution that the multitude of methods and implementations reported in home range studies reflects that no single technique will suffice in every situation and that a suite of potential tools is needed.

The kernel density estimator was introduced to ecologists by Worton (1989), and is becoming more widely used as it is considered to be one of the more reliable methods (Seaman and Powell, 1996). Kernel estimator is a non-parametric statistical method for estimating probability densities from asset of fixes. The kernel density estimator has the desirable qualities of directly producing a density estimate, and not being influenced by effects of grid size and placement (Silverman, 1986). It is also nonparametric, and has the potential to accurately estimate densities of any shape (Fryer, 1977).

Minimum Convex Polygon (MCP) is constructed by connecting the peripheral fixes, such that external angles are greater than 180° (Mohr, 1947). "Percent" MCP, sometimes referred to as "probability polygons" (Harris *et al*., 1990), or "mononuclear peeled polygons" (Kenward and Hodder, 1996), can be generated for a subset of fixes using one of several percentage selection methods available in the home range estimator. This method calculates a convex polygon for a percentage of the total fixes in a data set by calculating backwards from the polygon created for 100% of the fixes (White and Garrott, 1990). For example, a user can specify 85 as the percentage of fixes. The MCP method will first calculate the polygon for 100% of the fixes, after that the method will then excludes one fix from the perimeter of the polygon and recalculate the polygon. The choice of fix to be excluded is based upon its contribution to the total area of the polygon; a fix that increases the area the most is removed. The process is repeated fix-by-fix until only 85% of the fixes are left. Depending upon the input vector object, the MCP fitting may take more time for processing than the other methods. The MCP uses the percentage of fixes to control the area of the polygon that is created.

Harmonic algorithm computes the centre of greater occurrence and uses this centre to calculate a harmonic mean distribution (Dixon and Chapman, 1980). The Harmonic method calculates the reciprocal mean distance deviation, for each fix of a rectangular grid superimposed over the input vector object. The method then interpolates the values in the polygon boundary around the centre of greater occurrence. Each cell of the grid is divided into four triangles by "drawing" two diagonals from the four corners of the cell. The arithmetic mean of the reciprocal mean distance deviation is found within each grid cell by averaging the corner values of the cell. The mean is then assigned to the intersection of the diagonals in the cell. The method then begins searching for fixes from the input vector that lie within the cell. When a fix is encountered, its relative position in the grid cell is calculated by linear interpolation. Fixes of equal value are connected to form a contour. After the process has made all calculations for all cells and fixes, a polygon is produced that encompasses the centre of occurrence (Dixon and Chapman, 1980).

The Harmonic method does not produce a probability density function or use a smoothing factor (Laver and Kelly, 2008). Its outcome can be misleading, particularly if one or more fixes in the input vector object are located on or very close to one of the grid nodes. This method does not produce a probability density function, and hence it is difficult to interpret; it is sensitive to the size of the grid arbitrarily chosen by the user; it produces misleading results when fixes occur near grid-line intersections.

### 1.10 SPECIES HABITAT ANALYSIS

Habitat is defined as the type of place where an animal normally lives or, more specifically, the collection of resources and conditions necessary for its occupancy (Garshelis, 2000). Following this definition, habitat is organism specific (e.g., Blue Crane habitat, Wattled Crane habitat). Johnson (1980) defined selection as the process of choosing resources and preference as the likelihood of a resource being chosen if offered on an equal basis with others. Peek (1986) suggested that natural preferences exist even for resources not actually available. Furthering this concept, Rosenzweig and Abramsky (1986) characterized preferred habitats as those that confer high fitness and would therefore support a high equilibrium density (in the absence of other confounding factors, such as competitors). Thus utilization results from selection, selection results from preference, and preference presumably results from resource-specific differential fitness. In controlled experiments, preferences can be assessed directly by offering equal portions of different resources and observing choices that are made (Elston *et al*., 1996). In the wild, however, preferences must be inferred from patterns of observed use of environments with disparate, patchy, and often varying resources.

Generally, the purpose of determining preferences is to evaluate habitat quality or suitability, which can be defined as the ability of the habitat to sustain life and support population growth (Garshelis, 2000). Importance of a habitat is its quality relative to other habitats and its contribution to the sustenance of the population. Assessments of habitat quality and importance are thus based on the presumption that preference, and hence selection, are linked to fitness (reproduction and survival) and that preference can be gleaned from patterns of observed use (Garshelis, 2000).

There are several designs often used in habitat selection analysis (Garshelis, 2000). The first, generally called the use availability design, compares the proportion of time that an animal spends in each available habitat type (generally judged by the number of fixes, or less commonly, by the distance travelled) to the relative area of each type (Salas, 1996). The second, is referred to as the site attribute design, compares habitat characteristics of sites used by an animal to unused or random sites. These two designs generate measures of selection for various habitats or habitat attributes, and habitat quality or importance is inferred from the magnitude of this apparent selection (Garshelis, 2000).

### 1.10.1 USE AVAILABILITY DESIGN

From a review of habitat related studies of birds and mammals, Garshelis (2000) found that use availability design was utilized more often to assess selection and preference. Thomas and Taylor (2006) further categorized use availability studies into three approaches: one in which habitat use data are collected on animals that are not individually recognizable (visual sightings or sign), one in which data are collected on individuals (radio collared animals) but habitat availability is considered the same for all individuals (so individuals are typically pooled for analysis), and one in which use and availability are measured and compared for each individual.

Studies that pooled animals for analysis have commonly compared frequencies of use and availability for an array of habitats using a chi-square test (Garshelis, 2000). Determination of which habitat types were used more or less than expected is generally made by comparing availability of each habitat type to Bonferroni confidence intervals around the percentage use of each type. This procedure was described initially by Neu *et al*. (1974). According to (Marcum and Loftsgaarden, 1980), if the areas of available habitats are estimated (from sampling) rather than measured (from a map), use and availability should be compared with the chi-square test for homogeneity rather than goodness-of-fit. A chi-square goodness-of-fit test assumes that the availabilities are known constants against which use is compared, so if availabilities are actually estimated, with some sampling error, this test is more prone to indicate selection when there is none (type I error) (Thomas and Taylor 2006).

Various other methods of comparing use and availability have been introduced but less often used in wildlife habitat studies (Garshelis, 2000). Ivlev (1961) proposed an electivity index to measure relative selection of food items on a scale from -1 to 1; this has since been adopted for some habitat selection studies. However, Chesson (1978) noted that Ivlev's index may yield misleading results because it varies with availability even if preference is unchanged. The Manly-Chesson index is simply the proportional use divided by the proportional availability of each habitat, standardized so the values for all habitats sum to 1. As adapted to habitat studies, it is interpretable as the relative expected use of a habitat, had all types been equally available. Thus in an area with four habitats, an index of 0.25 for each habitat would indicate no preference, whereas deviations from this would indicate relative preference for or against certain habitat types.

Chesson (1978) extended this method to test for differences in habitat preference among individuals or sex age groups, and also showed how to test for statistically significant differences among preferences for different habitat types. Kincaid and Bryant (1983) offered an alternative method that scores relative differences between use and availability for habitats defined as geometric vectors.

Most studies using that uses these tests, often pool data among individuals, so that sightings or fixes become the sample units. Aebischer *et al.* (1993) pointed out that this constitutes pseudo replication and advised for comparing use to availability for each animal individually (so individuals are the sample units). Several methods have been developed specifically to do this. Of these, the most commonly used is Johnson's (1980), which is based on the difference between the rankings of habitat use and the rankings of habitat availability. This method also provides a means of detecting statistically significant differences among habitats, and not just a relative ordering of their selection. Moreover, because comparisons are made on an individual animal basis, habitat availability can be considered either within each individual home range, or within the study area as a whole. Johnson (1980) defined first order selection as that which distinguishes the geographic distribution of a species, second order selection as that which determines the composition of home ranges within a landscape, and third order selection as the relative use of habitats within a home range. Thus, both second and third order selections can be addressed with Johnson's (1980) technique: With chi-square tests it is possible (Boitani *et al*., 1994), but more difficult (because of sample size constraints) to consider both these levels of selection.

Alldredge and Ratti (1992) compared four methods (including the chi-square, and two others based on individual animal comparisons) in simulated conditions and found that none performed (with regard to type I and type II error rates) consistently better than the others. However, some methods are better suited for given situations. For example, because data for all animals are generally pooled for chi-square tests, unequal sampling among individuals could strongly affect the results if all individuals did not make similar selections. Conversely, the methods that weight animals equally, regardless of the amount of data collected on each, may be subject to spurious results caused by small sample sizes and variability among individuals.

Aebischer *et al*. (1993) offered what appears to be an improved procedure for comparing use with availability on an individual animal basis. This method (compositional analysis) has become increasingly popular because it enables assessment of both second order and third order selection and yields statistical comparisons (rankings) among habitats. Additionally, because the data are arranged analogous to an ANOVA, in which between group differences can be tested against within group variation among individuals, it provides a means of testing for differences among study sites (with different habitats, different animal density, or different predators or competitors), seasons or years (with different food conditions), sex age groups, or groups of animals with different reproductive outputs (Aebischer *et al*., 1993).

### 1.10.2 SITE ATTRIBUTE DESIGN

From a review of habitat related studies of birds and mammals, Garshelis (2000) found that site attribute design was not used as often as use availability studies. Site attribute studies differ from use availability studies in that they measure a multitude of habitat related variables at specific sites and attempt to identify the variables and the values of those variables that best characterize sites that are used, often for a specific activity (Garshelis, 2000). With this design, the dependent variable is not the amount of use, as with use availability studies, but simply whether each site was used or unused (or a random location with unknown use); the independent variables can be many and varied. Use availability studies generally just deal with broad habitat types, or if more variables are considered, they are analyzed individually (Gionfriddo and Krausman, 1986).

This design requires measurement of habitat variables at some defined site, usually one that serves some biological importance to the animal. Nest sites of birds are easily defined and biologically important, and hence are often the subject of studies of this nature. Habitat characteristics of breeding territories (Prescott and Collister, 1993), drumming sites (Stauffer and Peterson, 1985; Thompson *et al*., 1987), and roosting sites (Folk and Tacha, 1990) have also been investigated. Among mammals, studies have focused on characteristics of feeding sites (as evidenced by browsed or grazed vegetation; Edge *et al*., 1988), food storage sites (Smith and Mannan, 1994), resting sites (Ockenfels and Brooks, 1994), shelters (such as cliff overhangs, cavities, burrows, lodges, or dens; Nadeau *et al*., 1995), or areas recolonized by an expanding population (Hacker and Coblentz, 1993). Other studies have compared habitat characteristics of random location to sites where birds or mammals were observed, radio located, or known to have been from remaining sign (Lehmkuhl and Raphael, 1993).

The statistical procedures used in site attribute designs vary. Most have used multivariate analyses to differentiate combinations of variables that tend to be associated with the used sites. Discriminant Function Analysis (DFA) is the most popular of these. Logistic regression is an alternative, and is especially useful when the data consist of both discrete and continuous variables or are related to site occupancy in a nonlinear fashion (Nadeau *et al*., 1995).

There are various reasons that cause a problem of bias in habitat studies. The major reason is sampling (Garshelis, 2000). Interpretations of habitat use from visual observations of animals can vary among observers and sites can vary among types of habitats (because of differing vegetative density; Neu *et al.*, 1974), both of which can introduce biases in the data. For example, Powell (1994) noted that fisher tracks in snow were difficult to follow in habitats with dense vegetation, especially where fishers followed trails of snowshoe hares; in this case the bias against observing tracks in dense vegetation merely detracted from the overall conclusion that densely vegetated habitats were frequently used.

Counts of pellet groups (from ungulates or lagomorphs) may poorly reflect habitat use because defecation rates often vary with the food source, and hence the habitat type (Andersen *et al.*, 1992). Capture locations may be a poor indicator of habitat use because baits and other trap odours (from captures of other animals) may affect behaviours in an unpredictable way (Douglass, 1989).

Telemetry may also yield biased data on habitat use because the detection of an animal's radio signal may depend on the habitat it is in (GPS collars; Moen *et al.*, 1996), and location data obtained by triangulation have inherent associated errors. Intuitively, and as shown in computer simulations by White and Garrott (1986), errors in determining habitat use increase with increased habitat complexity and decreased precision in the telemetry system. Errors do not necessarily introduce bias, but can if patch size differs among habitats (detected use would be underrepresented in habitat types that tend to occur as small patches) or if the animal preferentially used the edge of some habitat types but not others.

Pooling individuals is common because sample sizes are typically too small to test for selection by individual (Garshelis, 2000). However, the statistical tests usually used assume independence among sample units, which is often not the case in studies that consider each location as a sample. Some techniques (Johnson, 1980; Aebischer *et al.*, 1993; Manly *et al.*, 1993; Thomas and Taylor, 2006) consider animals as sample units, so lack of independence among locations within individuals is not problematic. However, these methods are still subject to difficulties with lack of independence if animals are gregarious (attracted to the same habitats because they are attracted to each other; Gilbert and Bateman, 1983) or territorial (social exclusion precludes use of certain habitats), or if the study subjects are related (habitat preferences possibly affected by a common learning experience) or are from the same social group (group leaders dictate habitat use for all).

In an effort to alleviate the problem of a lack of independence among individuals, Neu *et al*. (1974) used groups of moose and Schaefer and Messier (1995) used herds of muskoxen as their sample units, rather than individual animals. Similarly, although Gionfriddo and Krausman (1986) monitored habitat use of individual radio collared mountain sheep, they considered groups of sheep their sample unit. However, Millspaugh *et al*. (1998) contend that animals in a herd should be considered independent individuals if they congregate because of a resource rather than because of a biological dependence on each other. They provide a hypothetical example with elk, where 99 of 100 radio tagged animals congregated at a winter feeding area in one habitat and the remaining individual used a second habitat; at other times of the year the elk did not associate with each other. In this case, they argue that each radio tagged individual should be considered an independent sample. In contrast, predators that hunt together in a pack and are thus dependent on one another cannot be considered to use habitats independently.

### 1.11 SPECIES HABITAT SUITABILITY ANALYSIS

Quantifying habitat quality is important for management of wildlife populations and conservation planning (Gerrard *et al*., 2001). Habitat suitability models have become increasingly important due to a global concern regarding the fate of wildlife and habitat (Lauver *et al*., 2002). These models provide predictions based on the relationship between a set of variables such as vegetation, water source, land use, elevation and aspect as well as presence data of the target species (Guisan and Zimmermann, 2000). One of the advantages of using GIS-based habitat model is that it is easy and faster to apply to large geographic areas because time and labour intensive collection of field data is not necessary (Larson *et al*., 2003). In addition, the projection of the generated functions to areas where environmental factors are known, but species have not been sampled, allows an optimal and cost effective method to predict species distribution in large areas (Guisan and Zimmermann, 2000).

Habitat suitability models have proven useful in predicting quality areas for species that are endangered, rare and threatened and those that have a patchy distribution over space and time (Gerrard *et al*., 2001). These models are then used as regulatory mechanism (Morris, 2003), with more endangered species receiving priority when designing and implementing conservation strategies (Woodhouse *et al*., 2000). Another application of habitat models have been in assessing the impact of land use on wildlife and therefore making predictions about the future (Austin *et al*., 1996).

There are a number of software packages used in developing habitat suitability models such as ModelBuilder, Biomapper and Maxent. ModelBuilder is an extension of ArcGIS that provides user friendly format for building spatial models. The ModelBuilder extension of ArcGIS 9.x allows manipulation of several attributes to produce a ranked and weighted overlay of relevant data to produce habitat suitability models.

The ModelBuilder extension provides a user friendly format for building spatial models. Model building Process Wizards and Diagramming Tools provide an interface in which the user can construct various types of spatial models. The habitat model is represented in a process flow diagram. These diagrams provide a visual means to construct, modify and document each habitat model. ModelBuilder also allows users to rerun the saved models using different input data, different function parameters, and different sets of values, thus enable evaluation of the results as needed. This functionality may be especially important when new or revised applicable data becomes available for establishing the delineated habitats.

Biomapper (Hirzel *et al*., 2002) is a kit of GIS and statistical tools designed to build habitat suitability models and maps for any kind of animal or plant. It is centred on the Ecological Niche Factor Analysis (ENFA) that allows computing models without the need of absence data. This method predicts a habitat suitability index rather than the likelihood of species occurrence (Hirzel *et al*., 2002). One key assumption of this method is that the presence data are an unbiased sample. This is unlikely to be the case with landscape scale studies that rely on presence information obtained from a non random sampling of the landscape (Hirzel *et al*., 2002). In addition, ENFA does not require much *priori* knowledge about the species habitat relationship in order to produce a statistically valid model (Hirzel *et al*., 2002). This has the unfortunate potential to separate the modeller from the true underlying ecological relationships (Belovsky *et al*., 2004). ENFA also tend to over predict occurrence (Brotons *et al*., 2004), yielding potential distributions (the fundamental niche) rather than existing distribution (the realized niche) (Brotons *et al*., 2004).

ENFA quantifies the niche occupied by a species by comparing its distribution in ecological space (''the species distribution'') with the distribution of all cells (the ''global distribution'') (Hirzel *et al*., 2002). ENFA focuses on the marginality of the species (how the species mean differs from the global mean) and environmental tolerance (how the species variance compares to the global variance). Species marginality gives indication of the species niche position whereas species tolerance is negatively associated to species specialisation and refers to its niche width, or breadth. ENFA uses a factor analysis with orthogonal rotations to (1) transform the predictor variables to a set of uncorrelated factors, and (2) to construct axes in a way that accounts for all marginality of the species in the first axis, and that minimizes tolerance in the following axes. There are different algorithms available in Biomapper to build habitat suitability maps from ENFA analysis (Hirzel *et al*., 2002).

Maxent (Phillips *et al.,* 2006) takes as input a set of environmental layers such as elevation, vegetation as well as a set of georeferenced occurrence locations, and produces a model of the range of the given species based on the maximum entropy approach for species habitat modelling.

It should be noted and considered that species ecological characteristics are critical in determining the accuracy of models and that it is difficult to predict generalist species distributions accurately and this is independent of the method used (Brotons *et al*., 2004). Being based on distinct approaches regarding adjustment to data and quality, habitat distribution modelling methods cover different application areas, making it difficult to identify one that should be universally applicable. Brotons *et al*. (2004) suggested that if absence data is available, methods using this information should preferably be used in most situations. Since data quality is likely to be a key issue affecting reliability of model predictions (Stockwell and Peterson, 2002), knowledge of the predictive performance of methods and their domain of application becomes an important issue at early stages of project development in surveys aimed at mapping species distributions.

For predictive models to be useful, they should provide geographical representations of the actual area where the species occurs (Brotons *et al.*, 2004). The reliability of predictive maps depends on many factors (or potential sources of error), but three stand out as the most important: (1) quality of biological data; (2i) predictive power of the predictors; and (3) modelling technique. While most recent work on the improvement of predictive modelling results has been devoted to the latter factor (Brotons *et al.*, 2004), the effects of the other two sources of error have been less studied, in spite of being highlighted (Araújo and Guisan, 2006). It is believed that accounting for the first source of error (quality of biological data) lies within the objectives of projects that aim to compile taxonomical and distributional data.

Good models need good biological data, with the best possible information about the presence and absence of the species (Araújo and Guisan, 2006). Species presence data constitutes the bulk of biodiversity databases while absences (localities or areas where the species is not present), however, are usually not recorded. Although biologists may know the places where a species is unlikely to be present, such data is usually not published. Thus, reliable absence data is often not available, and therefore true absences can not be distinguished from sites where the species is in fact present, but has not been recorded due to insufficient sampling effort. However, species are often absent from sites with environmentally favourable conditions due to biological interactions, dispersal limitations and or historical factors (Hanski, 1998), so that their actual and potential geographic distributions differ in space (Soberón and Peterson, 2005). If the aim of predictive maps is to depict the current distribution of species, absences from suitable areas should be taken into account (Lobo *et al.*, 2006), as well as predictors that account for the exclusion of species from some parts of their potential distribution.

## 1.12 SIGNIFICANCE OF THE STUDY

There are 15 crane species distributed worldwide, except Antarctica and South America (International Crane Foundation, 2001). Seven of the 15 crane species are listed as critically endangered (IUCN, 2004), amongst those species is the South Africa's Wattled Crane, which is facing extinction with only 235 individuals remaining (McCann *et al*., 2001). The need to conserve biodiversity is well recognised and supported worldwide (IUCN, 2004). It is therefore important that the habitat of species such as Blue Cranes be studied to help in conservation efforts that will eventually prevent further declines.

Grassland is one of seven biomes identified in South Africa; the other six are Forest, Fynbos, Nama-Karoo, Succulent Karoo, Savanna and Thicket (Mucina and Rutherford, 2006). While the Grassland Biome is considered to have extremely high species diversity, second only to the well known Fynbos Biome, and includes many rare and threatened species, it is regarded as one of the most critically threatened southern African ecosystems (Rutherford and Westfall, 1994). The Fynbos Biome situated in the Cape Floristic Kingdom, is often used as the norm with respect to plant species diversity as it contains one third of South African plant species but cover less than 6% of the area of the country (Mucina and Rutherford, 2006). It may seem that vast tracts of grassland still exist in the grassland biome, but much of it has been disturbed by cultivation, livestock grazing or the disruption of natural fire cycles, resulting in a severe decrease in the species diversity of plants, insects and other animals. Urbanization is a major additional influence on the loss of natural areas in this biome (Rutherford and Westfall, 1994).

Habitat destruction has emerged as the most severe threat to biodiversity worldwide, threatening about 85% of all species classified as "threatened" and "endangered" in the IUCN's Red List (IUCN, 2004). The populations of Blue Crane have also declined mainly due to destruction within its natural habitat - the grassland biome (Barnes, 2000). The Blue Crane has experienced a decline of more than 80% within the grassland of Mpumalanga Province (McCann *et al*., 2001). The grassland remains the most threatened biome (Rutherford and Westfall, 1986), in South Africa. The conservation of Blue Crane in the grasslands of the Mpumalanga Province may ensure the protection of this threatened biome, which in turn may also be beneficial to other species.

Blue Crane has been studied extensively both in the Grasslands and Fynbos Biome of South Africa. Most research concentrated on determining the characteristics of habitat variables (Allan, 1994; Morrison, 1998; McCann, 2000; Bidwell, 2004). However, home range sizes and habitat suitability analysis have never been studied for the Blue Crane. There were differences in habitat variables between nest and random sites (Bidwell, 2004). Blue Cranes were found to avoid anthropogenic disturbance and this behaviour is consistent with a study of crane nest site selection in grasslands (Morrison, 1998). This species avoided buildings, suggesting that the human settlements represent important sources of disturbance during breeding (Thompson and McGarigal, 2002).

### 1.13 STUDY SITES

The geographic extend of the study was from 24°14'S - 27°30'S and from 28°11'E - 31°9'E. This area includes the Nkangala and Gert Sibande district municipalities, as well as Dullstroom and Wakkerstroom towns, all located in Mpumalanga Province (Figure 1). Mpumalanga is one of the nine provinces of South Africa, situated in the eastern part of the country, north of KwaZulu-Natal and bordering Swaziland and Mozambique. This province is divided into three district municipalities: Nkangala (to the north of the province), Gert Sibande (to the south of the Province) and Ehlanzeni (to the north east of the province). Dullstroom is situated within the Nkangala district municipality (towards the north), while Wakkerstroom is located within the Gert Sibande municipality (towards the south). The study area is located at an altitude of 1880 m above sea level (Rutherford and Westfall, 1986). Rainfall in this province is over 500mm/yr (Ferrar and Lötter, 2007).

Mpumalanga Province contain three of South Africa's biomes: grassland (highveld and escapment hills), savanna (escarpment foothills and lowveld) and forest (south and east facing escarpment valleys) (Ferrar and Lötter, 2007). Grassland originally covered 61% of Mpumalanga, but 44% of this has been transformed by agriculture and other development. This substantial and irreversible reduction of the biome is due mainly to cultivation, especially industrial scale agriculture and timber growing. The upland grassland is a great collector of rain water for South Africa (Bredenkamp *et al*., 1996), which is a critical resource for this arid country (McClure, 1992).

In this manner, the grassland serves as the headwaters for three of South Africa's major river systems: the Vaal, the Thukela and Usutu-Pongola. Water levels in these rivers affect the entire country, as well as neighbours like Swaziland and Mozambique, through which the Usutu flows (McClure, 1992). Savanna used to cover 39% of Mpumalanga, but 25% of the original area of savanna has been transformed. Savannas are important for livestock, especially cattle and more recently the wildlife and tourism industry. Forests occur in small scattered patches, mostly in river valleys in the escarpment region. This biome requires high rainfall.

The land use types in this province can be classified as agriculture (76%), forestry (2%), industrial (4%) and conservation (8%) (Department of Agriculture and Land Administration, 2005). Urbanisation in the province is still relatively low (1.25%) and most of the land converted to another land use is under some form of cultivation (26%), including commercial plantations which comprise 8% of the total area of the province. This is significant when considering the high potential in the province for desertification (Breen and Begg, 1991).

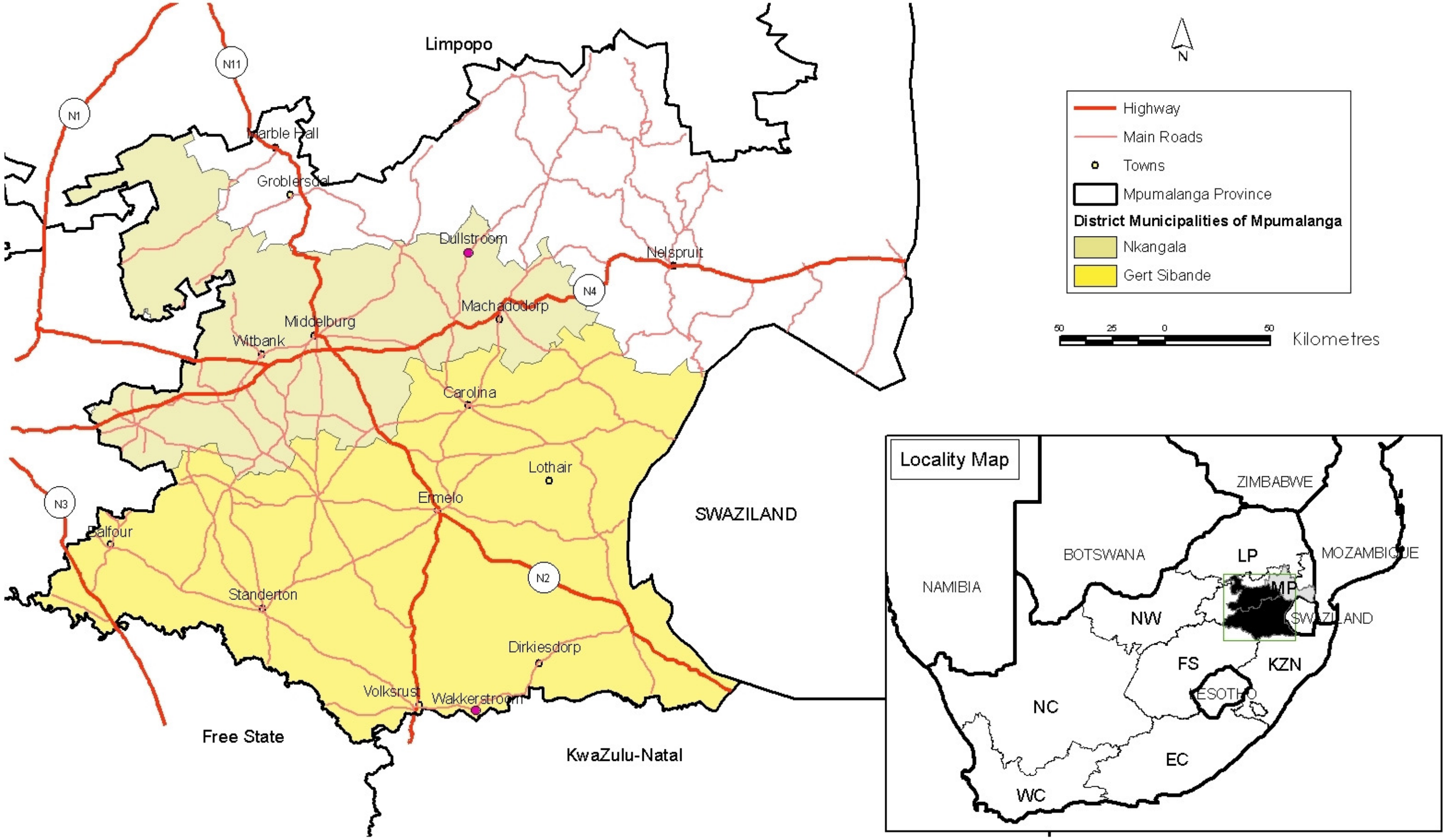

Figure 1: The location of the study area in Mpumalanga Province, showing the district municipalities and towns.

## 1.14 REFERENCES

AEBISCHER, N.J., ROBERTSON, P.A. & KENWARD, R.E. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology 74: 1313-1325.*

ALLAN, D.G. 1993. Aspects of the biology and conservation status of the Blue Crane Anthropoides paradiseus, and the Ludwig's Neotis ludwigii and Stanley's N. denhami stanleyi Bustards in southern Africa. MSc dissertation, University of Cape Town.

ALLAN, D.G. 1994. Haven for Blue Cranes in the southern Cape. *African Wildlife 48(4): 8-14.*

ALLAN, D.G. 1997. Blue Crane *(*Anthropoides paradiseus). In: Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Parker, A.J. & Brown, C.J. (Eds), The atlas of southern African birds: Non-passerines. Birdlife South Africa, Johannesburg.

ALLDREDGE, J.R. & RATTI, J.T. 1992. Further comparison of some statistical techniques for analysis of resources selection. *Journal of Wildlife Management 56: 1-9.*

ANDERSEN, R., HJELJORD, O. & SAETHER, B.E. 1992. Moose defecation rates in relation to habitat quality. *Alces 28: 95-100.*

ARAÚJO, M.B. & GUISAN, A. 2006. Five (or so) challenges for species distribution modelling. *Journal of Biogeography 33: 1677-1688.*

ARCHIBALD, G.W. & LEWIS, J.C. 1996. Crane biology. In: Ellis, D.H., Gee, G.F. & Mirande, C.M. (Eds), Cranes: Their biology, husbandry, and conservation. National Biological Service and International Crane Foundation, Washington.

ARCHIBALD, G.W. 1976. Crane taxonomy as revealed by the unison call. In: Lewis, J.C. (Ed), Proceedings of the International Crane Workshop. Oklahoma State University.

ARONOFF, S. 1989. Geographic Information Systems: A management perspective. WDL Publications, Ottawa.

AUSTIN, M.P., PAUSAS, J.G. & NICHOLLS, A.O. 1996. Patterns of tree species richness in relation to environment in southern–eastern New South Wales, Australia. *Australian Journal of Ecology 21: 154-164.*

BARNES, K.N. (Ed) 2000. The Eskom Red Data Book of South Africa, Lesotho and Swaziland. Birdlife South Africa, Johannesburg.

BELOVSKY, G.E., BOTKIN, D.B., CROWL, T.A., CUMMINS, K.W., FRANKLIN, J.F., HUNTER, M.L., JOERN, A., LINDEMAYER, D.B., MACMAHON, J.A., MARGULES, C.R. & SCOTT, J.M. 2004. Ten suggestions to strengthen the science of Ecology. *Bioscience 54: 345-351.*

BENNETT, G. 1833. Anthropoides Regulorum. A Catalogue of the specimens of Natural History. Sydney.

BIDWELL, M.T. 2004. Breeding habitat selection and reproductive success of Blue Cranes Anthropoides paradiseus in an Agricultural Landscape of the Western Cape. MSc dissertation, University of Western Cape.

BOITANI, L., MATTEI, L., NONIS, D. & CORSI, F. 1994. Spatial and activity patterns of wild boars in Tuscany, Italy. *Journal of Mammalogy 75: 600-612.*

BREDENKAMP, G., GRANGER, E. & VAN ROOYEN, N. 1996. North eastern Mountain grassland. In: Low, A.B. & Rebelo, A.G. (Eds), Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

BREEN, C.M. & BEGG, G.W. 1991. Conservation status of southern African wetlands. In: Huntley, B.J. (Ed), Biotic diversity in southern Africa: Concepts and conservation. Oxford University Press, Cape Town.

BROTONS, L., THUILLER, W., ARAÚJO, M.B. & HIRZEL, A.H. 2004. Presence-absence versus presence-only modelling methods for predicting bird habitat suitability. *Ecography 27: 437-448.*

BUCHANAN, J.B., ROGERS, R.E., PIERCE, D.J. & JACOBSON, J.E. 2003. Nest-site habitat use by White-headed Woodpeckers in the Eastern Cascade Mountains, Washington. *Northwestern Naturalist 84: 119-128.*

BURROUGH, P.A. 1986. Principles of Geographical Information Systems for land resources assessment. Clarendon Press, Oxford.

BURT, W.H. 1943. Territoriality and home range as applied to mammals. *Journal of Mammalogy 24: 346-352.*

CHESSON, J. 1978. Measuring preference in selective predation. *Ecology 59: 211-215.*

CLARKE, K.C. 2001. Getting started with Geographical Information Systems. Prentice Hall, New Jersey.

DAVIS, F.W., QUATTROCHI, D.A. & RIDD, M.K. 1991. Environmental analysis using integrated GIS and remotely sensed data: Some research needs and priorities. *Photogrammetric Engineering and Remote Sensing 57: 689-697.*

DEPARTMENT OF AGRICULTURE AND LAND ADMINISTRATION. 2005. Integrated resource information report. Provincial Department of Agriculture, Mpumalanga.

DETTMERS, R. & BART, J. 1999. A GIS modeling method applied to predicting forest songbird habitat. *Ecological Applications 9(1): 152-163.*

DIXON, K.R. & CHAPMAN, J.A. 1980. Harmonic mean measure of animal activity areas. *Ecology 61: 1040-1044.*

DOUGLASS, R.J. 1989. The use of radio-telemetry to evaluate microhabitat selection by deer mice. *Journal of Mammalogy 70: 648-652.*

DOWNS, J.A., GATES, R.J. & MURRAY, A.T. 2008. Estimating carrying capacity for Sandhill Cranes using habitat suitability of spatial optimization models. *Journal of Wildlife Management 72(8): 1813-1818.*

EDGE, W.D., MARCUM, C.L. & OLSON-EDGE, S.L. 1988. Summer forage and feeding site selection by elk. *Journal of Wildlife Management 52: 573-577.*

ELLIS, D.H., GEE, G.F. & MIRANDE, C.M. 1996. Cranes: Their biology, husbandry and conservation. Department of the Interior, National Biological Service, Washington.

ELSTON, D.A., ILLUS, A.W. & GORDON, I.J. 1996. Assessment of preference among a range of options using log ratio analysis. *Ecology 77: 2538-2548.*

ERICKSON, W.P., MCDONALD, T.L., GEROW, K.G., HOWLIN, S. & KERR, J.W. 2001. Statistical issues in resource selection studies with radiotracked animals. In: Millspaugh, J.J. & Marzluff, J.M. (Eds), Radio-tracking and animal populations. Academic Press, California.

FERRAR, A.A. & LÖTTER, M.C. 2007. Mpumalanga Biodiversity Conservation Plan Handbook. Mpumalanga Tourism & Parks Agency, Nelspruit.

FISCHER, M., HENK, J. & UNWIN, D.S. (Eds) 1996. Spatial analytical perspectives on GIS-GISDATA IV. Taylor and Francis Ltd, London.

FOLK, M.J. & TACHA, T.C. 1990. Sandhill Crane roost site characteristics in the North Platte River Valley. *Journal of Wildlife Management 54: 480-486.*

FRYER, M.J. 1977. A review of some non-parametric methods of Density estimation. *Journal of the Institute of Mathematics Applications 20: 335-354.*

GARSHELIS, D.L. 2000. Delusions in habitat evaluation: Measuring use, selection and importance. In: Boitani, L. & Fuller, T.K. (Eds), Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York.

GERRARD, R., STINE, P., CHURCH, R. & GILPIN, M. 2001. Habitat evaluation using GIS: A case study applied to the San Joaquin Kit Fox. *Landscape and Urban Planning 52: 239-255.*

GILBERT, F.F. & BATEMAN, M.C. 1983. Some effects of winter shelter conditions on white-tailed deer, Odocoileus virginianus, fawns. *Canadian Field-Naturalist 97: 391-400.*

GIONFRIDDO, J.P. & KRAUSMAN, P.R. 1986. Summer habitat use by mountain sheep. *Journal of Wildlife Management 50: 331-336.*

GMELIN. 1789. Ardea carunculata. *Systematic Naturale 1(2): 643.*

GONZALEZ, R.C. & WINTZ, P. 1977. Digital Image Processing. Addison-Wesley Publishing Company, Massachusetts.

GUISAN, A. & ZIMMERMANN, N.E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling 135: 147-186.*

GURNELL, J., CLARK, M.J., LURZ, P.W.W., SHIRLEY, M.D.F. & RUSHTON, S.P. 2002. Conserving Red Squirrels (Sciurus vulgaris): Mapping and forecasting habitat suitability using a Geographic Information Systems Approach. *Biological Conservation 105: 53-64.*

HACKER, A.L. & COBLENTZ, B.E. 1993. Habitat selection by mountain beavers recolonizing Oregon coast range clearcuts. *Journal of Wildlife Management 57: 847-853.*

HANSKI, I. 1998. Metapopulation dynamics. *Nature 396: 41-49.*

HARRIS, S., CRESSWELL, W.J., FORDE, W.J., TREWHELLA, T., WOOLLARD, T. & WRAY, S. 1990. Home range analysis using radio-tracking data – a review of problems and techniques particularly as applied to the study of mammals. *Mammal Review 20: 97-123.*

HAYNE, D.W. 1949. Calculation of size of home range. *Journal of Mammology 30: 1-18.*

HEIT, M., PARKER, H.D. & SHORTREID, A. 1996. GIS application in natural resources. Fort Collins, Colorado.

HEYWOOD, I., CORNELIUS, S. & CARVER, S. 2002. An introduction to Geographical Information Systems. Pearson Education Limited, England.

HIRZEL, A.H., HAUSSER, J., CHESSEL, D. & PERRIN, N. 2002. Ecological niche factor analysis: How to compute habitat suitability maps without absence data. *Ecology 87: 2027-2036.*

HOCKEY, P.A.R., DEAN, W.R.J. & RYAN, P.G. 2005. Robert's birds of southern Africa, 7th Edition. Trustees of the John Voelcker Bird Book Fund, Cape Town.

HOWELL, D.L. & CHAPMAN, B.R. 1997. Home range and habitat use of Red-Shouldered Hawks in Georgia. *Wilson Bulletin 109(1): 131-144*.

INTERNATIONAL CRANE FOUNDATION. 2001. "International Crane Foundation, Cranes: Their biology, husbandry and conservation." [On-line]. 17 March 2008.

IUCN (WORLD CONSERVATION UNION). 2004. 2004 IUCN Red List of Threatened Species. A Global Species Assessment. Gland & Cambridge, IUCN.

IVLEV, V.S. 1961. Experimental Ecology of the feeding of fishes. Yale University Press, New Haven.

JOHNSON, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology 61: 65-71.*

JOHNSON, D.N. 1992. The status of the cranes in Natal in 1989. In: Porter, D.J., Craven, H.S., Johnson, D.N. & Porter, M.J. (Eds), Proceedings of the first southern African Crane Conference. Southern African Crane Foundation, Durban.

JOHNSTON, C.A. 1998. Geographical Information Systems in Ecology. Blackwell Science, Oxford.

KENWARD, R.E. 1992. Quantity vs. quality: Programmed collection and analysis of radio-tracking data. In: Priede, I.G. & Swift, S.M. (Eds), Wildlife telemetry: Remote monitoring and tracking of animals. Ellis Horwood, Chichester.

KENWARD, R.E. & HODDER, K.H. 1996. Ranges V: An analysis system For biological location data. Institute of Terrestrial Ecology, Furzebrook Research Station, Wareham.

KINCAID, W.B. & BRYANT, E.H. 1983. A geometric method for evaluating the null hypothesis of random habitat utilization. *Ecology 64: 1463-1470.*

KONECNY, M.J. 1989. Movement patterns and food habitats of four sympatric carnivore species in Belize, Central America. In: Redford, K.H. & Eisenberg, J.F. (Eds), Advances in Neotropical Mammalogy. Sandhill Crane Press, Florida.

KOTOANE, M. 2003. Applying GIS to identify power lines that pose a high risk to Blue Crane (Anthropoides paradiseus) in the Overberg region. MA dissertation, University of Stellenbosch.

LANTER, D.P. 1994. A lineage metadata approach to removing redundancy and propagating updates in a GIS database. *Cartography and Geographic Information System 21(20): 91-98.*

LARSON, M.L., DIJAK, W.D., THOMPSON, F.R. & MILLSPAUGH, J.J. 2003. Landscape-level habitat suitability models for twelve wildlife species in southern Missouri. General Technical Report. St. Paul, MN, USDA.

LAUVER, C.L., BUSBY, W.H. & HISTLER, J.L. 2002. Testing a GIS model of habitat suitability for a declining grassland bird. *Environmental Management 30(1): 88-97.*

LAVER, P.N. & KELLY, M.J. 2008. A critical review of home range studies. *Journal of Wildlife Management 72(1): 290-298.*

LEHMKUHL, J.F. & RAPHAEL, M.G. 1993. Habitat pattern around Northern Spotted Owl locations on the Olympic Peninsula, Washington. *Journal of Wildlife Management 57:302-315.*

LE ROUX, J. (Ed) 2002. The biodiversity of South Africa 2002: Indicators, trends and human impacts. Struik Publishers, Cape Town.

LICHTENSTEIN, A.A.H. 1793. Anthropoides paradiseus. Catalogue Rerum naturalism rarissimarum Hamburgi. Humburg.

LINNAEUS, C. 1758. Systema Naturae per regna tria naturae, secundum classis, ordines, genera, species cum characteribus, differentiis, synonymis, locis. Laurentii Salvii, Stockholm.

LOBO, J.M., VERDU, J.R. & NUMA, C. 2006. Environmental and geographical factors affecting the Iberian distribution of flightless Jekelius species (Coleoptera Geotrupidae). *Diversity and Distributions 12: 179-188.*

MACLEAN, G.L. 1993. Roberts birds of southern Africa. John Voelcker Bird Book Fund, Johannesburg.

MANLY, B.F., MCDONALD, L.L. & THOMAS, D.L. 1993. Resource selection by animals. Statistical design and analysis for field studies. Chapman & Hall, London.

MARCUM, C.L. & LOFTSGAARDEN, D.O. 1980. A non mapping technique for studying habitat preferences. *Journal of Wildlife Management 44: 963-968.*

MCCANN, K. 2000. The crane train – a journey of conservation discovery. Vision of wildlife, ecotourism and the environment. Endangered Wildlife Trust, Johannesburg.

MCCANN, K., MORRISON, K., BYERS, A., MILLER, P. & FRIEDMANN, Y. (Eds) 2001. Blue Crane Anthropoides paradiseus: A Population and Habitat Viability Assessment Workshop. Conservation Breeding Specialist Group (SSC\IUCN). Apple Valley, MN.

MCCLURE, N. 1992. Washington's wetlands. Washington State Department of Ecology, Olympia.

MCSHEA, W.J., MACDONALD, M.V., MORTON, E.S., MEIER, R. & RAPPOLE, J.H. 1995. Long-term trends in habitat selection by Kentucky Warblers. *The Auk 112(2): 375-381.*

MEINE, C.D. & ARCHIBALD, G.W. 1996. The cranes: Status survey and conservation action plan. Gland, Switzerland.

MILLER, G.T. 2000. Living in the environment. Brooks/Cole publishing company, California.

MILLSPAUGH, J.J., SKALSKI, J.R., KERNOHAN, B.J., RAEDEKE, K.J., BRUNDIGE, G.C. & COOPER, A.B. 1998. Some comments on spatial independence in studies of resource selection. *Wildlife Society Bulletin 26: 232-236.*

MOEN, R., PASTOR, J., COHEN, Y. & SCHWARTZ, C.C. 1996. Effects of Moose movement and habitat use on GPS collar performance. *Journal of Wildlife Management 63: 659-668.*

MOHR, C. 1947. Table of equivalent populations of North American small mammals. *American Midland Naturalist 37: 223-249.*

MOORE, J.A., MILLER, H.C., DAUGHERTY, C.H. & NELSON, N.J. 2008. Fine scale genetic structure of a long-lived reptile reflects recent habitat modification. *Molecular Ecology 17: 4630-4641.*

MORRIS, D.W. 2003. Toward an ecological synthesis: a case for habitat selection. *Oecologia 136: 1-13.*

MORRISON, K.L. 1998. Habitat utilization and the population ecology of cranes in Dullstroom area of the Mpumalanga Province. MSc dissertation, University of Pretoria.

MUCINA, L. & RUTHERFORD, M.C. (Eds) 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria.

MULLER, S. 1776. Encyclopedia of Life. ICBP Technical Publications, Japan.

NADEAU, S., DECARIE, R., LAMBERT, D. & ST GEORGES, M. 1995. Nonlinear modeling of muskrat use of habitat. *Journal of Wildlife Management 59: 110-117.*

NEU, C.W., BYERS, C.R. & PEEK, J.M. 1974. A technique for analysis of utilization and availability data. *Journal of Wildlife Management 38: 541-545.*

NEWMAN, K. 1983. Newman's birds of southern Africa. Macmillan, Johannesburg.

OCKENFELS, R.A. & BROOKS, D.E. 1994. Summer diurnal bed sites of Coues White-tailed Deer. *Journal of Wildlife Management 58: 70-75.*

OKUBO, A. 1980. Diffusion and ecological problems: Modern Perspectives. Springer, Berlin.

PALLAS, P.S. 1773. Reise durch verschiedene Provinzen des Russischen Reichs. St Petersburg

PALLAS, P.S. 1811. Zoographia Rosso-Asiatica, sistens omnium Animalium in extensor Imperio Rossico et adjacentibus maribus observatorum recensionem, domicillia, mores et descriptions, anatomen atque icons plurimorum. Acadamiae scientiarum, Petropoli.

PEEK, J.M. 1986. A review of wildlife management. Prentice Hall, New Jersey.

PEREIRA, J.M.C. & ITAMI, R.M. 1991. GIS-based Habitat Modeling Using Logistic Multiple Regression: A Study of the Mt. Graham Red Squirrel. *Photogrammetric Engineering and Remote Sensing 57: 1475-1486.*

PERRIN, M.R. & CARRANZA, I.D. 2000. Habitat use by spotted-necked Otters in the KwaZulu-Natal Drakensberg, South Africa. *South African Journal of Wildlife Research 30: 8-14.*

PERRY, G. 1810. Systematics and taxonomy of birds. CSIRO Publisher, Australia.

PHILLIPS, S.J., ANDERSON, R.P. & SCHAPIRE, R.E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling 190: 231-259.*

POWELL, R.A. 1994. Effects of scale on habitat selection and foraging behaviour of fishers in winter. *Journal of Mammalogy 75: 349-356.*

PRESCOTT, D.R.C. & COLLISTER, D.M. 1993. Characteristics of occupied and unoccupied loggerhead shrike territories in south-eastern Alberta. *Journal of Wildlife Management 61: 346-352.*

PRZEVALSKI, N.M. 1876. Gruz nigricollis. Catalogue Rerum nationalism, Russia.

PULLAR, D. 1997. Rule-based modelling in GIS. University of Otago, New Zealand.

ROSENZWEIG, M.L. & ABRAMSKY, Z. 1986. Centrifugal community organization. *Oikos 46: 339-348.*

RUTHERFORD, M.C. & WESTFALL, R.H. 1986. Biomes of southern Africa: An objective categorization. Memoirs of the Botanical Survey of South Africa 54. Government Printer, Pretoria.

RUTHERFORD, M.C. & WESTFALL, R.H. 1994. Biomes of southern Africa: An objective categorization. Memoirs of the Botanical Survey of South Africa 63. National Botanical Institute, Pretoria.

SALAS, L.A. 1996. Habitat use by lowland tapirs (Tapirus terrestris L.) in the Tabaro River valley, southern Venezuela. *Canadian Journal of Zoology 74: 1452-1458.*

SAMUEL, M.D. & GARTON, E.O. 1987. Incorporating activity time in harmonic home range analysis. *Journal of Wildlife Management 51: 254-257.*

SEAMAN, D.E. & POWELL, R.A. 1996. An evaluation of the accuracy of Kernel density estimators for home range analysis. *Journal of Ecology 77: 2075-2085.*

SCHAEFER, J.A. & MESSIER, F. 1995. Habitat selection as a hierarchy: The spatial scales of winter foraging by muskoxen. *Ecography 18: 333-344.*

SCHOFF, G.H. 1991. Reflections: The story of cranes. International Crane Foundation, Wisconsin, USA.

SEEBER, G. 2003. Satellite Geodesy. Walter de Gruyter Inc, Berlin.

SHABANI, A.A. 2006. Identifying bird species as biodiversity indicators for terrestrial ecosystem management. MSc dissertation, RMIT University.

SILVERMAN, B.W. 1986. Density Estimation for Statistics and Data Analysis. Chapman and Hall, London.

SHAW, K. & HUDSON, V. 2001. Blue Crane Habitat in the Overberg/Swartland. In: Proceedings of the 13th Southern African Crane Working Group Workshop and the Southern African Strategy Meeting. South Africa Crane Working Group, Johannesburg.

SMITH, A.A. & MANNAN, R.W. 1994. Distinguishing characteristics of Mount Graham Red Squirrel Midden sites. J*ournal of Wildlife Management 58: 437-445.*

SOBERÓN, J. & PETERSON, A.T. 2005. Interpretation of models of fundamental ecological niches and species' distributional areas. *Biodiversity Informatics 2: 1-10.*

SODHI, N.S. & OLIPHANT, L.W. 1992. Hunting ranges and habitat use and selection of urban-breeding Merlins. *The Condor 94: 743-749.*

STAUFFER, D.F. & PETERSON, S.R. 1985. Seasonal micro-habitat relationships of Ruffed Grouse in south-eastern Idaho. *Journal of Wildlife Management 49: 605-610.*

STOCKWELL, D.R.B. & PETERSON, A.T. 2002. Effects of sample size on accuracy of species distribution models. *Ecological Modelling 148: 1-13.*

TACHA, T.C., NESBITT, S.A. & VOHS, P.A. 1992. Sandhill Crane. In: Poole, A., Stettenheim, P. & Gill, F. (Eds), The birds of North America: Life histories for the 21st century. The Academy of Natural Sciences of Philadelphia, Philadelphia.

TARBOTON, W.R. 1992. The population status of the Crowned Crane in the Transvaal. In: Porter, D.J., Craven, H.S., Johnson, D.N. & Porter, M.J. (Eds), Proceedings of the First Southern African Crane Conference, Southern African Crane Foundation, Durban.

TEMMINCK, C.J. 1835. Monographies de Mammalogie, ou description de quelques genres de mammiferes, don't les especes ont ete observees dans les differens musees de l'Europe. Van der Hoek, Leiden.

THOMAS, D.L. & TAYLOR, E.J. 2006. Study designs and tests for comparing resource use and availability II. *Journal of Wildlife Management 70: 324-336.*

THOMPSON, F.R., FREILING, D.A. & FRITZELL, E.K. 1987. Drumming, nesting, and brood habitats of ruffed grouse in an oak-hickory forest. *Journal of Wildlife Management 51: 568-575.*

THOMPSON, C.M. & MCGARIGAL, K. 2002. The influence of research scale on bald eagle habitat selection along the lower Hudson River, New York (USA). *Landscape Ecology 17: 569-586.*

URBAN, E.K., FRY, C.H. & KEITH, S. 1986. The birds of Africa. Academic Press, London.

VERNON, C.J., BOSHOFF, A.F. & STRETTON, W.S. 1992. The status and conservation of cranes in the Eastern Cape Province. In: Porter, D.J., Craven, H.S., Johnson, D.N. & Porter, M.J. (Eds), Proceedings of the First Southern African Crane Conference. Southern African Crane Foundation, Durban.

VOGIATZAKIS, I.N. 2003. GIS-based modelling and ecology: A review of Tools and Methods. *Geographical Paper 170: 1-29.*

WALKINSHAW, L.H. 1973. Cranes of the World. Winchester Press, New York.

WHITE, G.C. & GARROTT, R.A. 1986. Effects of biotelemetry triangulation error on detecting habitat selection. *Journal of Wildlife Management 50: 509-513.*

WHITE, G.C. & GARROTT, R.A. 1990. Analysis of wildlife radio tracking data. Academic Press, London.

WOODHOUSE, S., LOVETT, A., DOLMAN, P. & FULLER, R. 2000. Using GIS to select priority areas for conservation. *Computers, Environment and Urban Systems 24(2): 79-93.*

WORTON, B.J. 1989. Kernel methods for estimating the utilization distribution in home range studies. *Journal of Ecology 70: 164-168.*

YATES, T.L., MILLS, J.N., PARMENTER, C.A., KSIAZEK, T.G., PARMENTER, R.R., VAN DE CASTLE, J.R., CALISHER, C.H., NICHOL, S.T., ABBOTT, K.D., YOUNG, J.C., MORRISON, M.L., BEATY, B.J., DUNNUM, J.L., BAKER, R.J., SALAZAR-BRAVO, J. & PETERS, C.J. 2002. The ecology and evolutionary history of an emergent disease: Hantavirus Pulmonary Syndrome. *Bioscience 52: 989-998.*

# CHAPTER 2

# HOME RANGE SIZES OF BLUE CRANES DURING THE BREEDING SEASON

## 2.1 INTRODUCTION

When species becomes endangered, determining the size and composition of their home ranges is important for development of conservation strategies (Storch, 1995). Moreover, knowing about spatial behaviour of endangered species is an important initial step in establishing conservation measures. For instance, Bingham and Noon (1997) state that the most intensively used areas within the breeding home range should be identified and given priority in conservation plans. Understanding daily animal movement within an environment is an important element, as it reflects their use of resources in that particular environment (Jennrich and Turner, 1969).

## 2.2 AIMS AND OBJECTIVES

### 2.2.1 Aim

The aim of the study was to investigate the home range sizes of Blue Cranes during the breeding season.

### 2.2.2 Objective

The objective of the study was to determine the home range sizes of Blue Cranes during the breeding season.

## 2.3 METHODS

### 2.3.1 Data collection and processing

A systematic search was conducted to locate the nests and breeding pairs during the onset of the breeding season of 2005-2006. Two fieldworkers with local veld, including nest knowledge were stationed in Dullstroom and Wakkerstroom. Due to time constraints and the scope of this study, only seven nests were located and monitored (2 in Dullstroom and 5 in Wakkerstroom). Once a nest was located, the following information was recorded: (1) geographic location in decimal degrees, (2) the nest was given a name for easy identification, (3) geographic location of the nearest water source was recorded using a GPS, (4) land use was recorded by fieldworkers using direct observation and (5) elevation was recorded using a GPS and verified with a 20 m Digital Elevation Model (DEM) of the study area.

The second step was collection of fixes for the seven breeding pairs using direct observation method. Fieldworkers visited the nest sites on an average of two days per week, between 08H00 and 18H00, to collect fixes. Fixes were independent for statistical tests because they were collected at least 48 hours apart (Lair, 1987). Even though, early dawn and late dusk movement were not observed during this study, Blue Cranes have been reported (Aucamp, 1994; Hockey *et al*., 2005) to roost in water bodies close to their nests. Fieldworkers were cautious when approaching the nest sites in order to minimize disturbances. Once a breeding pair was observed, fieldworkers recorded the following: (1) number of adults, (2) date and time of day, (3) activity of the pair, (4) recording the current location of the observer using a GPS, (5) direction from the observer to the pairs was noted, (6) number of chicks (after hatching). The GPS had an accuracy level of an average 10 m, the datum was WGS 84, and coordinates were in degrees, minutes and seconds. All the data was recorded in Excel. Confusion of breeding pairs were minimised by two factors: (1) the nests were located far from each other (>4 km) and (2) this species has been reported by McCann (2000) to remain close to their nests when breeding. Fixes were collected until chicks were old enough to fly.

Once all the data was captured in Excel, the exact GPS coordinates were then estimated using a known point of reference (nest sites coordinates), and the direction of the pairs from the point were they were observed. Geographic locations were estimated to avoid disturbing the birds. The coordinates were converted into decimal degrees to allow further analysis using ArcGIS 9.2 program. Once the data was rectified, the Open Database Connectivity (ODBC) was used to link the data with ArcGIS 9.2 program. Statistical analysis was carried out using SYSTAT 5.0 (Wilkinson, 1990). Data from both areas were pooled because of the small sample size (n = 7).

### 2.3.2 Determining home range sizes

The Home Range extension 0.9 (Rodgers and Carr, 1998) of ArcView 3.2 was used to measure home range sizes. Home range sizes were calculated using the Adaptive Kernel (Worton, 1989) for seven breeding pairs (Table 1). The 50 and 95% Adaptive Kernel was designated as “core area” and “home range”, respectively. Adaptive Kernel estimator produces an area with little bias and gives surface estimates with low errors (Seaman and Powell, 1996). Secondly, it requires no unrealistic assumptions about the utilization distribution (Worton, 1989). Thirdly, it does not generally include large areas of unused habitat, and therefore gives a more conservative estimate than most home range estimators (Worton, 1989). Although a minimum of 30 fixes is recommended in home range analysis (Worton, 1987), four breeding pairs that had less than the recommended number, were included to improve the sample size.

### 2.3.3 Analysing habitat variables at nest sites

Home range parameters by themselves do not necessarily increase the understanding of wildlife resource use (Garshelis, 2000). However, when coupled with ecological and behaviour information, the size, shape, and use distribution of home ranges become meaningful biological parameters. Determination of habitat variables used by an animal is relatively straightforward in a GIS system using functions such as overlay tools.

Two habitat variables (water source and land use type) were recorded directly by fieldworkers at nest sites. Land use was recorded using direct observation. The location of the nearest water source was recorded with a GPS. Due to the small number of localities obtained for some pairs (Bethamoya, Naugevonden, Twyfelfontein, and Gelden), it was decided that fixes be used only for estimating home range sizes. Thus, no attempts were made to statistically analyse resources at each location.

Table 1: Home range sizes of seven Blue Crane pairs, calculated using Adaptive Kernel estimator.

| ID of pairs | Fixes | 50% Kernel (ha) | 95% Kernel (ha) |
|---|---|---|---|
| Elandhoek | 31 | 12.7 | 51.3 |
| Steenkampsberg | 30 | 7.7 | 24.4 |
| Bethamoya | 24 | 6.7 | 52.2 |
| Naugevonden | 18 | 10.4 | 55.5 |
| Twyfelfontein | 22 | 8.5 | 40.7 |
| Gelden | 28 | 7.8 | 37.3 |
| Hill | 32 | 9.1 | 42.9 |

## 2.4 RESULTS

### 2.4.1 Home range sizes

The home range sizes of seven breeding pairs were depicted at a scale of 1:20 000 on a map (Figure 2). The home ranges were in different shape and sizes. The Naugevonden pair had the highest home range (95% Adaptive Kernel), even though it had the lowest number of fixes (n = 18). The breeding pairs (Steenkampsberg, Elandhoek, Gelden and Hill) that had the highest number of fixes had the smallest home range sizes (Table 1). All the nests were located within the core area (50% Adaptive Kernel). The mean was 9,0 ha for the core area and 43,5 ha for the home range. There was a positive correlation ($r = 0.127$) between the number of fixes and core area sizes ($P = 0.05$). A negative correlation ($r = -0.446$) was observed between the number of fixes and home range sizes ($P = 0.05$). All the pairs had a successful breeding.

### 2.4.2 Habitat selection

Water source and land use were measured at nest sites (n = 7). The mean proximity of water sources to the nests was 300 m. Fieldworkers observed that nests were located within agricultural land (Pasture). Due to the small sample size, no attempts were made to apply any statistical analyses for these two variables. Some of the activities observed from the breeding pairs recorded included: feeding in mealie fields and sometimes in marshy areas, pairs observed at water sources, pairs guarding the nest, pairs keeping a close watch at chicks (Ramke, pers. comm). However, there was no consistency in recording of these activities.

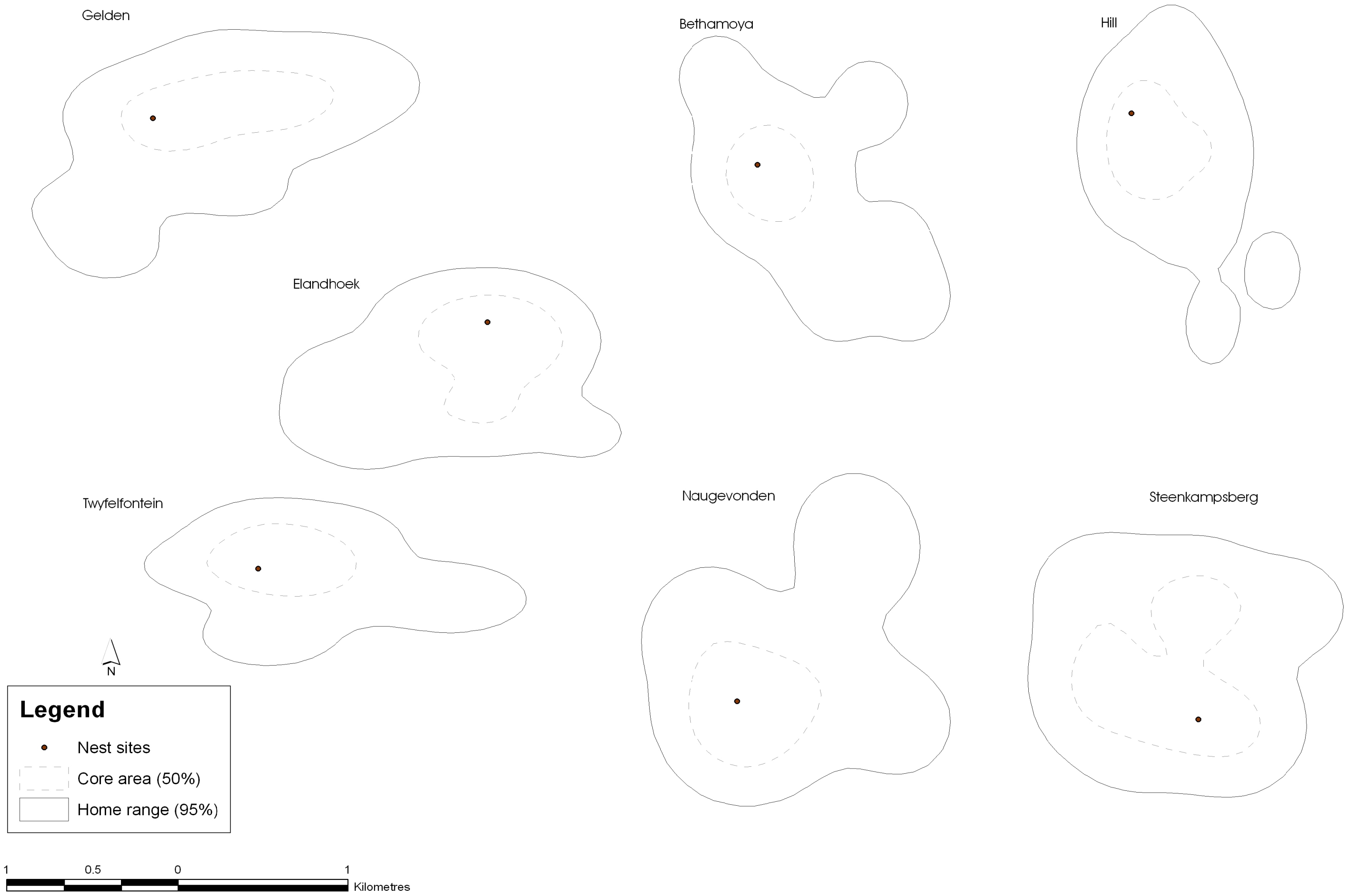

Figure 2: Home ranges of seven breeding pairs calculated using 50 and 95% Adaptive Kernel.

## 2.5 DISCUSSION AND CONCLUSIONS

Animals are known to maintain cognitive maps of the landscape, and they use these maps to remember where resources are located (Stamps, 1995). Therefore suitable breeding sites may be used for many years as long as resources are available. This species have been observed breeding in the same areas year after year (Ramke, pers. comm). Protection of the available breeding areas is essential to conserve the species. Home range studies showed that for a number of environmentally related reasons, certain portions within the home range are used more frequently (Burt, 1943). These are areas that are conceived as core to the home range. In the current study, nests were all located within the core area. These areas are often related to greater availability of resources such as food and shelter (Samuel and Garton, 1987). The agricultural land (pasture) might have contained food sources for the breeding pairs.

Analyses of habitat use within home ranges are necessary to understand the resource selection and distribution (Yates *et al*., 2002). Previous studies (Aucamp, 1994; Morrison, 1998; Barnes, 2000; McCann, 2000; Bidwell, 2004) have also reported Blue Cranes' preference for water source in close proximity. It has been reported by Bidwell (2004) that this species takes the chicks to water source after hatching. This species is also known to use water bodies for roosting (Meine and Archibald, 1996). It was, however, not possible to establish whether they used the nearest water sources for roosting since they were not monitored at night. Nests were also found located within agricultural land. This variable was also not statistically analysed due to the small sample size. However, previous studies (Allan, 1994; Barnes, 2000; Bidwell, 2004) have reported Blue Cranes' preference for nesting within agricultural land (mainly pasture).

There was no overlap observed between home range sizes of the seven breeding pairs. A number of reasons might have contributed to that. Firstly, the distance measured using ArcGIS program showed that there was a distance of >4 km between the breeding sites. Secondly, overlapping might have occurred at times when the birds were not monitored. That is early dawn and late dusk, as the birds were monitored roughly between 08H00-18H00. Thirdly, the breeding pairs were monitored on an average of two days per week.

The following limitations were observed during the study. The observation method for collecting fixes has a disadvantage of not being able to allow systematic monitoring (for example, if the pairs were not near the nests, it was not possible to locate their position), breeding pairs might have overlapped during unmonitored days, and there were also problems with exact locations of birds due to the fact that fixes were only estimated to avoid disturbing the birds. In view of the above mentioned limitations, the generality of the results is open to debate. The observation and conclusions presented here are admittedly based upon a small sample size. However, a foundation has been developed for future home range analysis of this species.

In light of the results of this study, it is recommended that future studies examine breeding home range in more detail and should address the nature and extent of individual variation in habitat use and should attempt to identify important habitat characteristics within home ranges. Until better information is available, management of breeding habitat should be approached conservatively. It is also, recommended that future research should use a more robust method of location monitoring such as radio tracking which ensures that data is collected accurately over a longer period. Radio tracking has been used overwhelmingly in home range studies (Squires *et al*., 1993; Howell and Chapman, 1997; Jansen *et al*., 2000; Ratcliffe and Crowe, 2001; Dickson and Beier, 2002; Boal *et al*., 2003; Vega Rivera *et al*., 2003). Kenward (1992) also indicated a preference on radio tracking and noted that this technique can improve the quality and quantity of fixes.

## 2.6 REFERENCES

ALLAN, D.G. 1994. Haven for Blue Cranes in the southern Cape. *African Wildlife 48(4): 8-14.*

AUCAMP, E. 1994. Blue Crane update. Vision of Wildlife, Ecotourism and the Environment in southern Africa. Endangered Wildlife Trust 1994 Annual, Johannesburg.

BARNES, K.N. (Ed) 2000. The Eskom Red Data Book of South Africa, Lesotho and Swaziland. Birdlife South Africa, Johannesburg.

BIDWELL, M.T. 2004. Breeding habitat selection and reproductive success of Blue Cranes Anthropoides paradiseus in an Agricultural Landscape of the Western Cape. MSc dissertation, University of Western Cape.

BINGHAM, B.B. & NOON, B.R. 1997. Mitigation of habitat "take": Application to habitat conservation planning. *Conservation Biology 11: 127-139.*

BOAL, C.W., ANDERSON, D.E. & KENNEDY, P.L. 2003. Home range and residency status of northern Goshawks breeding in Minnesota. *The Condor 105: 811-816.*

BURT, W.H. 1943. Territoriality and home range as applied to mammals. *Journal of Mammalogy 24: 346-352.*

DICKSON, B.G. & BEIER, P. 2002. Home range and habitat selection by adult cougars in southern California. *Journal of Wildlife Management 66: 1235-1245.*

GARSHELIS, D.L. 2000. Delusions in habitat evaluation: Measuring use, selection and importance. In: Boitani, L. & Fuller, T.K. (Eds), Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York.

HOCKEY, P.A.R., DEAN, W.R.J. & RYAN, P.G. 2005. Robert's birds of southern Africa, 7th Edition. Trustees of the John Voelcker Bird Book Fund, Cape Town.

HOWELL, D.L. & CHAPMAN, B.R. 1997. Home range and habitat use of Red-Shouldered Hawks in Georgia. *Wilson Bulletin 109(1): 131-144.*

JANSEN, R., LITTLE, R.M. & CROWE, T.M. 2000. Habitat utilization and home range of the Redwing Francolin, Francolinus levaillantii, in highland grasslands, Mpumalanga Province, South Africa. *African Journal of Ecology 38: 329-338.*

JENNRICH, R.I. & TURNER, F.B. 1969. Measurement of non-circular home range. *Journal of Theoretical Biology 22: 227-237.*

KENWARD, R.E. 1992. Quantity vs. quality: Programmed collection and analysis of radio-tracking data. In: Priede, I.G. & Swift, S.M. (Eds), Wildlife telemetry: Remote monitoring and tracking of animals. Ellis Horwood, Chichester.

LAIR, H. 1987. Estimating the location of the focal center in red squirrel home ranges. *Ecology 68: 1092-1101.*

MCCANN, K. 2000. The crane train – a journey of conservation discovery. Vision of wildlife, ecotourism and the environment. Endangered Wildlife Trust, Johannesburg.

MEINE, C.D. & ARCHIBALD, G.W. 1996. The cranes: Status survey and conservation action plan. Gland, Switzerland.

MORRISON, K.L. 1998. Habitat utilization and the population ecology of cranes in the Dullstroom area of the Mpumalanga Province. MSc dissertation, University of Pretoria.

RATCLIFFE, C.S. & CROWE, T.M. 2001. Habitat utilization and home range size of helmeted guineafowl Numida meleagris in the Midlands of KwaZulu-Natal Province, South Africa. *Biological Conservation 98: 333-345.*

RODGERS, R. & CARR, A.P. 1998. The Home Range extension for ArcView™ Beta Test Version 0.9. Users Manual. Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources.

SAMUEL, M.D. & GARTON, E.O. 1987. Incorporating activity time in harmonic home range analysis. *Journal of Wildlife Management 51: 254-257.*

SEAMAN, D.E. & POWELL, R.A. 1996. An evaluation of the accuracy of Kernel density estimators for home range analysis. *Journal of Ecology 77: 2075-2085.*

STAMPS, J. 1995. Motor learning and the value of familiar space. *American Naturalist 146: 41-58.*

STORCH, I. 1995. Annual home ranges and spacing patterns of Capercaillie in central Europe. *Journal of Wildlife Management 59: 392-400.*

SQUIRES, J.R., ANDERSON, S.H. & OAKLEAF, R. 1993. Home range size and habitat-use patterns of nesting prairie falcons near oil developments in northern Wyoming. *Journal of Field Ornithology 64(1): 1-10.*

VEGA RIVERA, J.H., AYALA, D. & HAAS, C.A. 2003. Home range size, habitat use, and reproduction of the Ivory-billed Woodcreeper Xiphorbyncbus flavigaster in dry forest of western Mexico. *Journal of Field Ornithology 74(2): 141-151.*

WILKINSON, L. 1990. SYSTAT: The system for statistics. SYSTAT, Inc. Evanston.

WORTON, B.J. 1987. A review of models of home range for animal movement. *Ecological Modelling 38: 277-298.*

WORTON, B.J. 1989. Kernel methods for estimating the utilization distribution in home range studies. *Journal of Ecology 70: 164-168.*

YATES, T.L., MILLS, J.N., PARMENTER, C.A., KSIAZEK, T.G., PARMENTER, R.R., VAN DE CASTLE, J.R., CALISHER, C.H., NICHOL, S.T., ABBOTT, K.D., YOUNG, J.C., MORRISON, M.L., BEATY, B.J., DUNNUM, J.L., BAKER, R.J., SALAZAR-BRAVO, J. & PETERS, C.J. 2002. The ecology and evolutionary history of an emergent disease: Hantavirus Pulmonary Syndrome. *Bioscience 52: 989-998.*

# CHAPTER 3

# HABITAT SELECTION BY BLUE CRANES DURING THE BREEDING SEASON

## 3.1 INTRODUCTION

Management of wildlife populations, whether to conserve threatened species, or promote biodiversity, generally entails habitat management (Dettmers and Bart, 1999). Thus a fundamental step in the management of wildlife requires the identification of habitat characteristics needed to sustain populations of target species (Garshelis, 2000; Marzluff *et al*., 2001; Vavra, 2005; Carter *et al*., 2006). To assess a species' preferences and avoidance, researchers commonly study habitat use and using the results to infer selection and preference (Garshelis, 2000). Presumably, species should reproduce or have greater survival success. Thus, once habitats can be ordered by their relative preference, they can be evaluated as to their relative importance in terms of fitness. Identifying patterns and features associated with selected habitats can indicate which combinations of resources are most suitable to animals (Marzluff *et al*., 2001).

## 3.2 AIMS AND OBJECTIVES

### 3.2.1 Aim

The aim of the study was to investigate habitat selection by Blue Cranes during the breeding season.

### 3.2.2 Objective

The objective of the study was to determine resource selection by Blue Cranes during the breeding season.

## 3.3 METHODS

### 3.3.1 Data collection and processing

Habitat variables and actual breeding data were obtained for analysis of habitat selection of the Blue Crane (Table 2). Habitat variables were obtained from various sources and in different geographic coordinates.

Table 2: GIS layers and sources.

| Data | Source | Projection | Format |
|---|---|---|---|
| Nests | SACWG | Geographic | Vector (.Shp) |
| Vegetation | CSIR | UTM | Raster (Landsat-5 TM) |
| Land use | CSIR | UTM | Raster (Landsat-5 TM) |
| Water bodies | Survey General | Geographic | Vector (.Shp) |
| Elevation | Survey General | Geographic | Raster (DEM) |
| Slope | Survey General | Geographic | Raster (DEM) |
| Aspect | Survey General | Geographic | Raster (DEM) |
| Built-up land | Survey General | Geographic | Vector (.Shp) |
| Roads | Survey General | Geographic | Vector (.Shp) |
| Railway line | Survey General | Geographic | Vector (.Shp) |

#### 3.3.1.1 Nesting data

Nest sites were located by SACWG fieldworkers through a systematic search, relying on their knowledge of the local area and historic breeding sites during 2005-2006 breeding season. On finding a nest, a GPS position was obtained. The GPS positions together with associated non-spatial data were captured in Excel. A total of 47 and 27 nests were observed and recorded in Dullstroom and Wakkerstroom, respectively. The nesting data were rectified into decimal degrees to allow compatibility with GIS program. Using Open Database connectivity, data from Excel was linked with ArcGIS 9.2 program for further analysis.

#### 3.3.1.2 Environmental variables

One of the advantages of using GIS technology is that some data can be created from other data sets (Heywood *et al*., 2002). For example, vegetation and land use data were created from satellite images (LANDSAT-5 TM).

ERDAS IMAGINE 9.0 (Leica GeoSystems @ Atlanta, Georgia) was used to process satellite images. The procedure for satellite image processing was the same for vegetation and land use, although they were processed separately. Satellite images used in this study covered a much larger area than the study area. ERDAS IMAGINE also provides a tool called subsetting, which is designed to be used to extract the necessary portion from the images. Subsetting refers to breaking out a portion of a large file into one or more smaller files (Gonzalez and Wintz, 1977). Subsetting is helpful because it reduces the size of the image files to include only the area of interest (AOI). This not only eliminates the extraneous data in the file, but it speeds up processing due to the smaller amount of data to process. Subset utility command of ERDAS IMAGINE was used with specified parameters set in inquire box to create AOI from the entire images.

Multiple images were stitched in ERDAS IMAGINE using a command mosaic. This command offers the capability to stitch images together so one large, cohesive image of an area can be created (Jensen, 1996). It is necessary for the images to contain map and projection information, but they do not need to be in the same projection or have the same cell sizes.

The next step was to perform classification of images. ERDAS IMAGINE provides two methods of image classification: (1) supervised classification and (2) unsupervised classification. Unsupervised classification was chosen for both vegetation and land use classification. Unsupervised classification is simpler than supervised because signatures are automatically generated by the ISODATA algorithms (Lillesand and Kiefer, 1994).

Unsupervised classification is a method in which an image processing program searches for natural groupings of similar pixels called clusters (Jensen, 1996). This method is more computer-automated. It enables the user to specify some parameters that the computer uses to uncover statistical patterns that are inherent in the data. These patterns do not necessarily correspond to directly meaningful characteristics of the scene, such as contiguous, easily recognized areas of a particular land use or vegetation types. They are simple clusters of pixels with similar spectral characteristics than it is to sort pixel into recognizable categories.

Unsupervised training is dependent upon the data itself for the definition of classes. It is then the analyst's responsibility, after classification, to attach meaning to the resulting classes (Jensen, 1996). It is therefore important that the user have a good understanding of the area mapped in order to be able to decide the type land use and vegetation classes that the pixels of each cluster represent. Hard copies of vegetation and land use maps were obtained from Environmental Potential Atlas (ENPAT). Classifications used in the maps were followed for image classification. For example, vegetation and land use was classified into 14 (Table 3) and six classes (Table 4), respectively, as it was done in the hard copy maps. Unfortunately, due to time and financial constraints there was no attempt to ground truth the results obtained from satellite image classification.

Table 3: Vegetation types classified from satellite images.

| |
|---|
| North Eastern Sandy Highveld |
| Themeda veld |
| Bankenveld |
| Piet Retief Sourveld |
| Sourish Mixed Bushveld |
| Mixed Bushveld |
| Northern Tall Grassveld |
| Lowveld Sour Bushveld |
| Cymbopogon veld |
| Lowveld |
| Springbok Turf Thornveld |
| North Eastern Mountain Sourveld |
| Highland Sourveld |
| Southern Tall Grassveld |

Table 4: Land use types classified from satellite images.

| |
|---|
| Agriculture |
| Conservation |
| Forestry |
| Mining and Quarries |
| Degraded land |
| Vacant/Unspecified land |

### 3.3.1.3 Physiographic data

Physiographic data included elevation, slope and aspect which were created from a 20 m Digital Elevation Model (DEM). A DEM refers to any digital representation of the continuous variations of relief over space (Burrough, 1986). Spatial Analyst Tools were used to create elevation, slope and aspect from the DEM. Elevation was measured in 20 m interval to determine the height above sea level within the study area. Slope was measured to identify the rate of change in percentage. Aspect identifies the cardinal directions of slope. The cell values in aspect use compass direction ranging from 0 to 360. North is 0, east is 90, south is 180, and west is 270. Flat represent a raster cell that have zero slope (flat areas) and such cells are assigned a value of -1.

### 3.3.1.4 Anthropogenic variables

Anthropogenic variables included built-up land, roads and railway line. Built-up land (settlements and commercial land) and roads categories included both main and secondary.

## 3.4 DATA ANALYSIS

A site attribute design was followed to measure habitat selection. Garshelis (2000) defines site attribute design as a measurement of habitat variables at specific sites and attempts to identify the variables and the values of those variables that best characterize sites that are used (often for specific activity). With this design, the dependent variable is not the amount of use but simply whether each site was used or unused (or a random location with unknown use); the independent variables can be many and varied.

### 3.4.1 Habitat assessment at nest and random sites

Nine habitat variables were quantified and measured at the nest sites (n = 74). After measuring the habitat variables at the nest sites, the same variables were studied at randomly selected sites within the Nkangala and Gert Sibande municipalities, combined. A larger sample (n = 200) of random sites was selected using Generate Random Points command of Hawth's analysis tools for ArcGIS (Beyer, 2004). This sample ensured that most parts of the study area were covered.

Analysis was carried out using the GIS techniques such as overlay, proximity, and select by theme and SQL query). Proximity analysis is one of the fundamental tools for spatial analysis (Chou, 1997), that generates new polygons based on the distance from selected map features. Proximity analysis tools also allow data organised on separate layers to be manipulated as if they are on one layer, which helps to identify relationships among different features (Chou, 1997). Proximity analysis is measured using a buffer command. Creating buffers is one of the core functionalities in GIS (Hutchinson and Daniel, 2000). In this type of analysis, distance is a primary element, which is often expressed as Euclidean distance (Chou, 1997). A buffer command has option to specify the buffer distance, such as whether the contiguous resultant polygons be dissolved or not, the number of rings around the buffered feature and the distance units. A prerequisite for this kind of analysis is that the layers should be in the same coordinate system.

Overlay is a type of analysis that unites different map layers and then assigns them a common reference base (Clarke, 2001). In order to perform overlay analysis, all the variables were classified into appropriate categories (aspect was classified into nine cardinal directions – north, south, east, west, north east, south east, north west, south west and flat). Therefore, by overlaying nest and random sites on to aspect layers, it was possible to observe and record individual sites within aspect classes.

The "theme-on-theme selection" offers the user the spatial relationship types such as "are completely within", "intersect", "are within a distance of", "have their centres in", "completely contain", and so forth. These options offer the user flexibility to accurately define the problem at hand and perform relevant analysis. Unlike the normal joins operated with tables, map overlays use the spatial reference system (Chrisman, 1997), to discover connections between data layers.

In the same way, the layers should be in the same coordinate system before any kind of analysis is carried out. Select by location command allows selection of features from one or more layers based on where they are located in relation to the features in another layer.

Water sources included marshes, vleis, perennial pans, non-perennial pans, dry pans, lakes, dams and large reservoirs. Using create multiple buffer wizard, a multiple ring buffer was created for water sources at an interval of 500 m. Nests and random sites were then overlaid onto a buffered water source layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each buffer distance. The records were then captured using Excel for statistical analysis.

Vegetation was classified into 14 classes (Table 3). Since vegetation classes were classified already, nests and random sites were overlaid onto vegetation layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each classes. The records were then captured using Excel for statistical analysis.

Land use was classified into six classes (Table 4). Since Land use was already classified into classes, nests and random sites were overlaid onto land use layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each classes. The records were then captured using Excel for statistical analysis.

Elevation was ranging from 1700-2200 m above sea level. Nests and random sites were overlaid onto elevation layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at different altitude. The records were then captured using Excel for statistical analysis.

Percent slope was classified into six classes (0-4, 5-9, 10-14, 15-19, 20-24, and >25). Nests and random sites were overlaid onto slope layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each slope. The records were then captured using Excel for statistical analysis.

Aspect was classified into cardinal directions (north, south, west, east, north east, north west, south east, south west and flat). Nests and random sites were overlaid onto aspect layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each slope. The records were then captured using Excel for statistical analysis.

Multiple buffer wizard was used to create a multiple ring buffer around built-up land layer at an interval of 500 m. Nests and random sites were then overlaid onto a buffered built-up land. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each buffer distance. The records were then captured using Excel for statistical analysis.

Multiple buffer wizard was used to create a multiple ring buffer around road layer at an interval of 500 m. Nests and random sites were then overlaid onto a buffered road layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each buffer distance. The records were then captured using Excel for statistical analysis.

Multiple buffer wizard was used to create a multiple ring buffer surrounding railway line layer at an interval of 500 m. Nests and random sites were then overlaid onto a buffered railway line layer. Using ArcGIS selection tool (select by theme command), individual nests and random sites were recorded at each buffer distance. The records were then captured using Excel for statistical analysis.

### 3.4.2 Statistical analysis

Statistical analysis was performed with Statistical Analysis System software (SAS Institute, 2001). A paired sample *t*-tests was used to determine whether there were differences in the individual habitat variables between nests and random sites. Chi-square tests were used for categorical variables (vegetation, land use, slope and aspect), to determine the difference between those variables on nests and random sites. Multivariate Analysis of Variance (MANOVA) was also used to test the significance of all the dependent variables at once. Habitat variables that had significant differences when compared at nests and random locations were entered into a Logistic regression (Hosmer and Lemeshow, 1989) was used to identify the combination of variables that most effectively discriminated the nest and random sites. Logistic regression was preferred over discriminant analysis because it allows analysis of both continuous and categorical variables (Norusis, 1994). A stepwise procedure was also used to retain variables that significantly improved the model.

### 3.5 RESULTS

The mean elevation at the nest sites was 1930 m above sea level. The mean elevation at random sites was 1424 m above sea level. As expected, the results (Table 5) shows a highly statistically significant difference between the elevation at nests and those at random sites (*t = -18.14; df = 272; P = <0.0001*).

The mean proximity of water bodies to the nests was 0.191 Km. The mean proximity of water bodies to random sites was 4.038 Km. There was a highly significant difference (Table 5) between the mean proximity of water sources to the nests and random sites (*t = 8.86; df = 272; P = <0.0001*).

The mean proximity of roads to the nests was 2.350 km. The mean proximity of roads to random sites was 0.444 Km. There was a significant difference (Table 5) between the mean roads of the nests and random sites (*t = -17.79; df = 272; P = <0.000*). This species selected sites that were significantly further from roads.

The mean proximity of railway line to the nests was 6.209 km. The mean proximity of railway line to random sites was 0.389 Km. There was a highly significant difference (Table 5) between the mean railway line to the nests and random sites (*t = -17.03; df = 272; P = <0.0001*). This species selected sites that were significantly further from railway line than random sites.

The mean proximity of built-up land to the nests was found to 12.19 km. The mean proximity of built-up land to random sites was 2.129 Km. There was a highly significant difference (Table 5) between the mean built-up land to the nests and random sites (*t = -19.12; df = 272; P = <0.0001*). This species definitely avoided built-up land.

Table 5: Habitat variables measured at Blue Crane nests and random sites.

| Variables | Nest sites (n=74) | Random sites (n=200) | *t* | P |
|---|---|---|---|---|
| Water bodies | 0.191 | 4.038 | 8.86 | <0.0001 |
| Elevation | 1930 | 1424 | -18.14 | <0.0001 |
| Built-up land | 12.19 | 2.129 | -19.12 | <0.0001 |
| Roads | 2.350 | 0.444 | -17.79 | <0.0001 |
| Railway line | 6.209 | 0.389 | -17.03 | <0.0001 |

Table 6: Summary of Chi-square statistics for Aspect.

| Aspect | Observed Nest sites | Observed Random sites | Expected Nest sites | Expected Random sites |
|---|---|---|---|---|
| North | 40 | 17 | 15.394 | 14.606 |
| East | 10 | 7 | 4.5912 | 12.409 |
| South | 8 | 11 | 5.1314 | 13.869 |
| West | 3 | 21 | 6.4818 | 17.518 |
| North East | 1 | 9 | 2.7007 | 7.2993 |
| South East | 7 | 18 | 6.7518 | 18.248 |
| South West | 5 | 17 | 5.9416 | 16.058 |
| North West | 0 | 14 | 3.781 | 10.219 |
| Flat | 0 | 86 | 23.226 | 62.774 |

Table 7: Summary of Chi-square statistics for Slope.

| Slope | Observed Nest sites | Observed Random sites | Expected Nest sites | Expected Random sites |
|---|---|---|---|---|
| 0-4 | 5 | 77 | 22.146 | 59.845 |
| 5-9 | 0 | 23 | 6.2117 | 16.788 |
| 10-14 | 3 | 27 | 8.1022 | 21.898 |
| 15-19 | 3 | 4 | 1.8905 | 5.1095 |
| 20-24 | 26 | 37 | 17.015 | 45.985 |
| >25 | 37 | 32 | 18.635 | 50.365 |

Table 8: Summary of Chi-square statistics for Land use.

| Land use | Observed Nest sites | Observed Random sites | Expected Nest sites | Expected Random sites |
|---|---|---|---|---|
| Agriculture | 66 | 32 | 26.467 | 71.533 |
| Conservation | 8 | 6 | 3.781 | 10.219 |
| Forestry | 0 | 10 | 2.7007 | 7.2993 |
| Mining and Quarries | 0 | 3 | 0.8102 | 2.1898 |
| Degraded land | 0 | 1 | 0.2701 | 0.7299 |
| Vacant | 0 | 148 | 39.971 | 108.03 |

Table 9: Summary of Chi-square statistics for Vegetation.

| Vegetation | Observed Nest sites | Observed Random sites | Expected Nest sites | Expected Random sites |
|---|---|---|---|---|
| NE Sandy Highveld | 48 | 25 | 10.533 | 28.467 |
| Themeda veld | 12 | 30 | 11.343 | 30.657 |
| Bankenveld | 14 | 33 | 21.876 | 59.124 |
| Piet Retief Sourveld | 0 | 3 | 0.8102 | 2.1898 |
| Sourish Mixed Bushveld | 0 | 17 | 4.5912 | 12.409 |
| Mixed Bushveld | 0 | 18 | 4.8613 | 13.139 |
| Northern Tall Grassveld | 0 | 15 | 4.0511 | 10.949 |
| Lowveld Sour Bushveld | 0 | 24 | 6.4818 | 17.518 |
| Cymbopogon veld | 0 | 6 | 1.6204 | 4.3796 |
| Lowveld | 0 | 4 | 1.0803 | 2.9197 |
| Springbok Turf Thornveld | 0 | 5 | 1.3504 | 3.6496 |
| NE Mountain Sourveld | 0 | 2 | 0.5401 | 1.4599 |
| Southern Tall Grassveld | 0 | 9 | 2.4307 | 6.5693 |
| Highland Sourveld | 0 | 9 | 2.4307 | 6.5693 |

Nest sites and random points were located at a highly significantly different aspect classes ($X^2 = 106.9061; df = 8; P = <0.0001$) (Table 6). The north facing aspect was used more than expected during breeding. Other aspect categories that were used were south, east and south east. There was a complete avoidance of flat and north west facing slope. Random points were distributed in all aspect classes with more points occurring in flat areas.

Nests sites and random sites were located at a highly significantly different slope classes ($X^2 = 63.2867; df = 5; P = <0.0001$) (Table 7). Steeper slope (20 - >25) was used more than expected during breeding, while random points were distributed in all slope classes with more occurring in a gentle slope.

Nests sites and random points were located at a highly significantly different land use classes ($X^2 = 147.2860; df = 5; P = <0.0001$) (Table 8). The agricultural land was mostly preferred during breeding, with few nests occurring in conservation areas and a complete avoidance of other land use types. Random points were distributed in all land use types, with more in vacant land as expected.

Nests sites and random points were located at a highly significantly different vegetation classes ($X^2 = 85.7959; df = 13; P = <0.0001$) (Table 9). North eastern sandy highveld was mostly preferred, followed by Themeda and Bankenveld. Other vegetation types were completely avoided during breeding, while random points were distributed in all vegetation categories.

Combination of all the variables entered for MANOVA, showed a highly significant difference according to Wilks' Lambda (*P = <0.0001*). This shows that the difference on some of the treatments of the all the measured variables, affirms that the difference observed in the univariate analyses on each of the variables are most likely real differences.

Logistic regression (PROC LOGISTIC, SAS Institute 2001) model identified elevation and built-up land as the variables that most effectively discriminated the nest and random sites. Using Wald chi square statistics, elevation had an average squared canonical correlation of (*ASCC = 0.74*), followed by built-up land (*ASCC = 0.57*).

### 3.6 DISCUSSION AND CONCLUSIONS

Most of the findings were consistent with those from previous studies. Nest sites were located at a significantly higher elevation. Preference of the Blue Cranes to breed at higher elevation may be associated with low human disturbance which are often limited in high altitude areas.

Nest sites were found at a marked close proximity to the nearest water source. Availability of water close to the nests has been observed in various studies (Meine and Archibald, 1996; McCann *et al*., 2001; Bidwell, 2004), and is regarded as one of the most important habitat variables for the Blue Crane during breeding activity. Some explanations that have been proposed for the Blue Crane's preference of water source include: (1) water sources enable non-incubating Blue Crane to roost relatively close to the nest, and (2) short distance may facilitate Blue Crane leading nestling to water source shortly after hatching, reducing predation risk and increasing nestling survival (Bidwell, 2004).

Bidwell (2004) observed a tendency of this bird to avoid anthropogenic factors. In this study, sites that were significantly further from anthropogenic factors were selected (built-up land, roads and railway line). Anthropogenic factors have been reported as an important source of disturbance to the breeding cranes (Thompson and McGarigal, 2002). However, Meine and Archibald (1996) have found that cranes can adapt better to human interference if they are not harmed or disturbed. For example, the Eurasian Cranes in the more populated southern parts of Sweden are known to be less shy and they nest in agricultural areas, often close to human activities (Bylin, 1987). It is therefore assumed that with other minimal threats, this species may acclimatize to anthropogenic factors, as one nest was found located under a power line (Shaw, pers. comm).

A North facing slope was preferred during breeding. Van Heerden and Hurry (1987), argue that a North facing slope is warmer and hence more conducive to nesting than South facing slopes. A North facing aspect maximise insulation to the nest in the morning and reduce excessive heat stress in the afternoon, thus buffering daily temperature extremes.

This species overwhelmingly chose agricultural land for nesting. In this study agricultural land was preferred (Ramke, pers. comm). The same results were also observed by Allan (1994). Allan (1994) associated this preference to availability of food sources within the cultivated lands.

Walkinshaw (1973) described the vegetation around Blue Crane nests as dominated by the grass species *Pennisetum, Andropogon, Arundinella, Miscanthidium, Ascolepis, Pycreus, Cyperus, Scirpus,* and *Carex.* Morrison (1998) reported other plant species in addition to some of those described by Walkinshaw (1973), comprising *Aristida junciformis, Themeda triandra, Tristachya leucothrix* and *Monocymbium ceresiiforme*, followed by Themeda veld and Bankenveld. The current study did not investigate plant species at a finer scale. However, it may be assumed that dominant species associated with the vegetation type were present in the same vegetation types found in this study. Dominant plant species associated with preferred vegetation (north east sandy highveld, themeda and bankenveld) found in this study include *Tristachya leucothrix, Themeda triandra, Eragrostis racemosa, Monocymbium ceresiiforme, Eragrostis plana, Eragrostis scleranta, Cymbopogon plurinodis, Eragrostis Chloromelas, Eragrostis capensis, Andropogon schirensis* (adapted from Mucina and Rutherford, 2006).

The overall conclusion is that the environmental, physiographic and anthropogenic variables used in this part of the study, has an influence on the Blue Crane nest sighting. It is therefore, recommended that conservation efforts of this species should take into consideration sites with these variables.

## 3.7 REFERENCES

ALLAN, D.G. 1994. Haven for Blue Cranes. *African Wildlife 48(4): 8-14.*

BEYER, H.L. 2004. Hawth's Analysis Tools for ArcGIS. Environmental Systems Research Institute, California.

BIDWELL, M.T. 2004. Breeding habitat selection and reproductive success of Blue Cranes Anthropoides paradiseus in an Agricultural Landscape of the Western Cape. MSc dissertation, University of Western Cape.

BURROUGH, P.A. 1986. Principles of Geographical Information Systems for land resources assessment. Clarendon Press, Oxford.

BYLIN, K. 1987. The common crane in Sweden - distribution, numerical status, habitats, breeding success and need of protection. In: Archibald, G.W. & Pasquier, R.F. (Eds), Proceedings of the 1983 International Crane Workshop. International Crane Foundation, Wisconsin.

CARTER, G.M., STOLEN, E.D. & BREININGER, D.R. 2006. A rapid approach to modeling species-habitat relationships. *Biological Conservation 127: 237-234.*

CHOU, Y. 1997. Exploring spatial analysis in GIS. OnWord Press, Entrada.

CHRISMAN, N. 1997. Exploring Geographic Information Systems. John Wiley and Sons, New York.

CLARKE, K.C. 2001. Getting started with Geographical Information Systems. Prentice Hall, New Jersey.

DETTMERS, R. & BART, J. 1999. A GIS modeling method applied to predicting forest songbird habitat. *Ecological Applications 9(1): 152-163.*

GARSHELIS, D.L. 2000. Delusions in habitat evaluation: Measuring use, selection and importance. In: Boitani, L. & Fuller, T.K. (Eds), Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York.

GONZALEZ, R.C. & WINTZ, P. 1977. Digital Image Processing. Addison-Wesley Publishing Company, Massachusetts.

HEYWOOD, I., CORNELIUS, S. & CARVER, S. 2002. An introduction to Geographical Information Systems. Pearson Education Limited, England.

HOSMER, D.W. & LEMESHOW, S. 1989. Applied Logistic regression. John Wiley and Sons, New York.

HUTCHINSON, S. & DANIEL, L. 2000. Inside ArcView GIS. OnWord Press, Denmark.

JENSEN, J.R. 1996. Introductory Digital Image Processing: A Remote Sensing Perspective. Prentice-Hall, New Jersey.

LILLESAND, T.M. & KIEFER, R.W. 1994. Remote Sensing and image interpretation. Wiley and Sons, New York.

MARZLUFF, J.M., BOWMAN, R. & DONNELLY, R. 2001. Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell.

MCCANN, K., MORRISON, K., BYERS, A., MILLER, P. & FRIEDMANN, Y. (Eds) 2001. Blue Crane Anthropoides paradiseus: A Population and Habitat Viability Assessment Workshop. Conservation Breeding Specialist Group (SSC\IUCN). Apple Valley, MN.

MEINE, C.D. & ARCHIBALD, G.W. 1996. The cranes: Status survey and conservation action plan. Gland, Switzerland.

MORRISON, K.L. 1998. Habitat utilization and the population ecology of cranes in the Dullstroom area of the Mpumalanga Province. MSc dissertation, University of Pretoria.

MUCINA, L. & RUTHERFORD, M.C. (Eds) 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria.

NORUSIS, M.J. 1994. SPSS advanced statistics 6.1. SPSS Inc., Chicago.

SAS INSTITUTE, INC. 2001. Software release 8.02. Cary, North Carolina.

THOMPSON, C.M. & MCGARIGAL, K. 2002. The influence of research scale on Bald Eagle habitat selection along the lower Hudson River, New York (USA). *Landscape Ecology 17: 569-586.*

VAN HEERDEN, J. & HURRY, L. 1987. Southern Africa's weather patterns: An introductory guide. Acacia Books, Pretoria.

VAVRA, M. 2005. Livestock grazing and wildlife: Developing compatibilities. *Rangeland Ecology and Management 58: 128-134.*

WALKINSHAW, L.H. 1973. Cranes of the World. Winchester Press, New York.

# CHAPTER 4

# A GIS-BASED HABITAT SUITABILITY MODEL FOR THE BREEDING SITES OF BLUE CRANES

## 4.1 INTRODUCTION

Habitat destruction and degradation may cause irreversible fragmentation, which is the most significant known cause for species decline (Li *et al.*, 2002). The distribution of organisms is directly linked to habitat availability, hence identifying spatial relationships between organisms and environmental feature is an essential step to plan and promote sustainable conservation measures (Grinnel, 1917; Desbiez *et al.*, 2009). Moreover, understanding the environmental features that predict species occurrence is important for planning successful conservation strategies (Pereira and Itami, 1991; Harvey and Weatherhead, 2006). The application of geospatial techniques has assumed an increasingly important role in wildlife conservation by providing means for modelling potential distributions of species and their habitats (Zarri *et al.*, 2008).

## 4.2 AIMS AND OBJECTIVES

### 4.2.1 Aim

The aim of the study was to investigate suitable breeding sites for Blue Cranes.

### 4.2.2 Objective

The objective of the study was to predict suitable breeding sites for Blue Cranes.

## 4.3 METHODS

### 4.3.1 Data acquisition and processing

Habitat variables (Table 10) were selected based on the results obtained in chapter three and existing literature (Allan, 1994; Morrison, 1998; McCann, 2000; McCann *et al.*, 2001; Bidwell, 2004). Many factors influence the distribution of a species (Gough and Rushton, 2000), and it is not possible to quantify all of these components of a species niche. It is therefore necessary to create a simplified representation of the species niche by identifying those factors that are considered to have the greatest influence on species' distribution.

Variables used in habitat suitability studies are chosen on the premise that if modified they would be expected to affect the capability of the habitat to support the species (United States Fish and Wildlife Service, 1981). It is therefore important to thoroughly understand species' habitat needs and the significant habitat variables should be practically measurable within the constraints of model application. Identifiable requisites for the breeding sites include food, foraging sites, avoidance of human-induced disturbances, and protection from predators. Habitat variables chosen in this study covered some of the important requisites for the breeding activity of the Blue Crane.

Table 10: Weights assigned to habitat variables using Analytic Hierarchy Process.

| Variables | Weights |
|---|---|
| Water bodies | 30.5 |
| Vegetation | 21.7 |
| Land use | 16.2 |
| Elevation | 10.8 |
| Built-up land | 7.6 |
| Aspect | 5.3 |
| Roads | 3.6 |
| Slope | 2.5 |
| Railway line | 1.9 |

### 4.3.2 The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a methodology for multi-criteria analysis and decision-making, developed in the late 1970's by Saaty (1980). It has become one of the most widely used techniques as shown by the extensive literature published in journals and books (Golden *et al.*, 1989; Shim, 1989; Vargas, 1990; Saaty, 2000; Forman and Gass, 2001; Golden and Wasil, 2003). AHP is a method for decision making in situations where multiple objectives are present. The AHP was designed to help with multiple-criteria decisions. According to Saaty (1980) there are some important components of the AHP that includes: (1) the structuring of a problem into a hierarchy consisting of a goal and subordinate features (decomposition), (2) pair-wise comparisons between elements at each level (evaluation), and (3) propagation of level-specific, local priorities to global priorities (synthesis). Subordinate levels of a hierarchy, may include: objectives, scenarios, events, actions, outcomes, and alternatives. Alternatives courses of action to be compared appear at the lowest level of the hierarchy. AHP can prevent subjective judgement errors and increase the likelihood that results are reliable.

To determine the weights of the individual variables, a pair-wise comparison matrix was constructed (Table 13). All the columns in the normalised pair-wise comparison matrix should sum to one (Saaty, 1980). This compares the relative importance of the variables in relation to each other to derive a habitat layer weights based on a 1-9 scale of relative importance (Table 11), developed by Saaty (1980).

The ability of AHP to test for consistency is one of the method's greatest strengths (Saaty, 1980). The AHP view of consistency is based on the idea of cardinal transitivity. For example, if requirement A is considered to be two times more important than requirement B, and requirement B is considered to be three times more important than requirement C, then perfect cardinal consistency would imply that requirement A be considered six times more important than requirement C. in this way, if the participants judge requirement A to be less important than requirement C, it implies that a judgemental error exists and the prioritization matrix is inconsistent.

Table 11: Analytic Hierarchy Process scale of paired of comparisons (after Saaty, 1980).

| **Intensity of importance** | **Definition and explanations** |
|---|---|
| 1 | Equal importance – Two activities contribute equally to the objectives |
| 3 | Moderate importance – Experience and judgement strongly favour one activity over another |
| 5 | Essential or strong importance – Experience and judgements strongly favour one activity over another |
| 7 | Demonstrate importance – An activity is strongly favoured and its dominance is demonstrated in practice |
| 9 | Extreme importance – The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8 | Intermediate values |
| Reciprocal of above numbers | If an activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*. |

A key step is the establishment of priorities through the use of the pair-wise comparison procedure. An important consideration is the consistence of the judgements made when constructing the pair-wise comparison. Decision makers' feelings and preferences remain inconsistent and may lead to wrong conclusions. Such inconsistencies might be of the form that while a factor B is preferred over A, and A preferred over C, it can therefore be expected that B will be preferred over C. Should this not be the case then there is evidence for inconsistency in the judgements.

Therefore, Saaty (1977) provided the Consistency Ratio (CR) which is a single numerical index to check for consistency of the pair-wise matrix. It is defined as the ratio of the Consistency Index (CI) to an average Consistency Index (RI; Table 12), thus CR = CI/RI. The RI value is read from a table provided by Saaty and Vargas (1991). In the current study, the number of requirements was 9, therefore the RI was 1.45 (Table 12). Consistency ratio is designed so that values of ratio exceeding 0.1 are indicative of inconsistent judgements indicating that the decision maker should do a revision of the preference matrix (Saaty and Vargas, 1991). Consistency ratio for this study was 0.035, which was indicative of consistent judgement as it was less than the recommended value of 0.1 (Dai *et al*., 2001).

Table 12: Values for *RI* (Saaty and Vargas, 1991; with n = order of matrix).

| **n** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.51 |

Table 13: A pair-wise comparison of habitat suitability variables for Blue Crane breeding sites.

| | **Water** | **Vegetation** | **Land use** | **Elevation** | **Built-up land** | **Aspect** | **Roads** | **Slope** | **Railway line** |
|---|---|---|---|---|---|---|---|---|---|
| Water | 0.353 | 0.177 | 0.117 | 0.089 | 0.71 | 0.060 | 0.049 | 0.046 | 0.039 |
| Vegetation | 0.424 | 0.212 | 0.106 | 0.069 | 0.053 | 0.043 | 0.036 | 0.029 | 0.027 |
| Land use | 0.399 | 0.266 | 0.133 | 0.067 | 0.044 | 0.033 | 0.023 | 0.019 | 0.017 |
| Elevation | 0.349 | 0.262 | 0.175 | 0.087 | 0.044 | 0.029 | 0.022 | 0.018 | 0.015 |
| Built-up land | 0.307 | 0.246 | 0.184 | 0.123 | 0.061 | 0.031 | 0.020 | 0.0153 | 0.012 |
| Aspect | 0.272 | 0.226 | 0.181 | 0.136 | 0.091 | 0.045 | 0.023 | 0.015 | 0.011 |
| Roads | 0.235 | 0.201 | 0..201 | 0.134 | 0.101 | 0.067 | 0.034 | 0.017 | 0.011 |
| Slope | 0.213 | 0.187 | 0.187 | 0.133 | 0.107 | 0.08 | 0.053 | 0.027 | 0.013 |
| Railway line | 0.196 | 0.174 | 0.174 | 0.130 | 0.109 | 0.087 | 0.065 | 0.043 | 0.022 |

### 4.3.3 DEVELOPING HABITAT SUITABILITY MODEL

Nine habitat variables (Table 10) were used to develop the model for the Blue Crane breeding sites. The model was developed using ModelBuilder extension. This ArcGIS extension helps to create a flow chart, of session that captures the geographic data, the spatial functions that operate on the data, and the order of those function. When running the model, all the spatial functions in the project essentially runs itself. ModelBuilder allows adding, deleting, or replacing any data set, spatial operation, or variable within a spatial operation. This extension is designed to work primarily with grid data sets; therefore, all vector layers (water source, built-up land, and roads) were first converted into raster using Feature to Raster Conversion Tool of ArcToolbox.

The habitat variables contained different data and some were measured in different units (Slope measured in percentage, water bodies in metres and aspect in cardinal directions). In order to be able to combine all the data sets, the command Reclassify was used to classify variables into a common scale of 1 (least suitable) to 6 (highly suitable).

Once all the variables were converted into a common scale, a command Weighted Overlay (McGregor, 1998), was used to produce an overall suitability map (Figure 13). Since habitat variables do not have the same importance to the location of the breeding sites, each layer was assigned weights (Table 10), based on its influence using AHP (Saaty, 1980). The areas identified as highly suitable were assigned a value of 6 and the restricted areas were classified as “restricted” in order to exclude such areas from being identified as suitable (Burnside *et al*., 2002).

North eastern sandy highveld, Themeda and Bankenveld represented suitable vegetation for breeding sites selection. Other vegetation types (Piet Retief sourveld, Sourish mixed bushveld, Mixed Bushveld, Northern tall grassveld, Lowveld sour bushveld, Cymbopogon, Lowveld, Springbok flats turf thornveld, North Eastern mountain sourveld, Southern tall grassveld, and Highland sourveld), were classified as less suitable.

Land use variable was classified into a scale of 1 to 6 using equal interval method (Figure 5). Agricultural land was followed by conservation and forestry, while restricting mining and quarries, vacant, and degraded land from being classified as suitable areas.

Elevation layer was first converted into raster data using Raster Conversion Tool. This layer was also classified into a scale of 1 to 6 using equal interval method (Figure 6). Higher altitudes were classified as suitable areas.

Aspect was classified into nine classes (north, south, east, west, northeast, northwest, southeast, southwest, and flat), which were then reclassified into a scale of 1 to 6 applying an equal interval method (Figure 7). The north facing aspect was given a value of 6, followed by south, while restricting flat and North West facing aspects.

A 20 m Digital Elevation Model (DEM) was used to calculate slope. Slope was measured in percent (0-4, 5-9, 10-14, 15-19, 20-24, and >25). Figure 8 shows a reclassified slope on a scale of 1 to 6 using an equal interval method. Steeper slopes were given higher values as suitable sites, while restricting gentle slopes.

Anthropogenic variables (built-up land, roads and railway line) layers were also classified into a scale of 1 to 6 applying an equal interval method. Sites that were further from nest sites were given higher value as suitable areas.

Using a command Weighted Overlay, all variables were combined. Suitability model based on the assigned weighting (Table 10), was then produced. The model was then applied to the study area to predicted suitable breeding areas. During the process of model construction, ModelBuilder enabled experimenting with parameter values, using different input data, running the model over and over again until the desired results were reached (Figure 12).

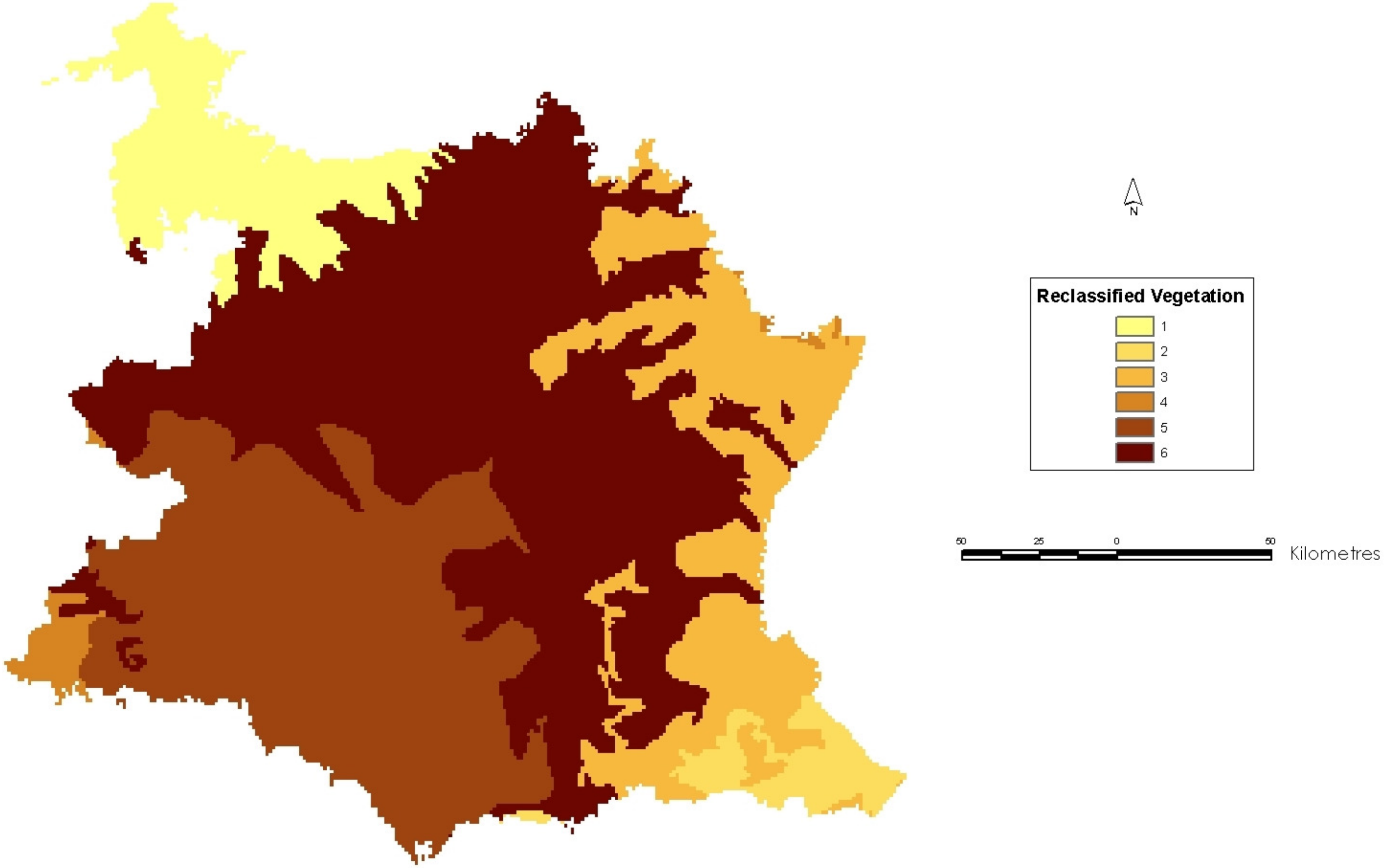

Figure 3: Reclassified Vegetation, where 6 represents the most suitable and 1 represents the least suitable site.

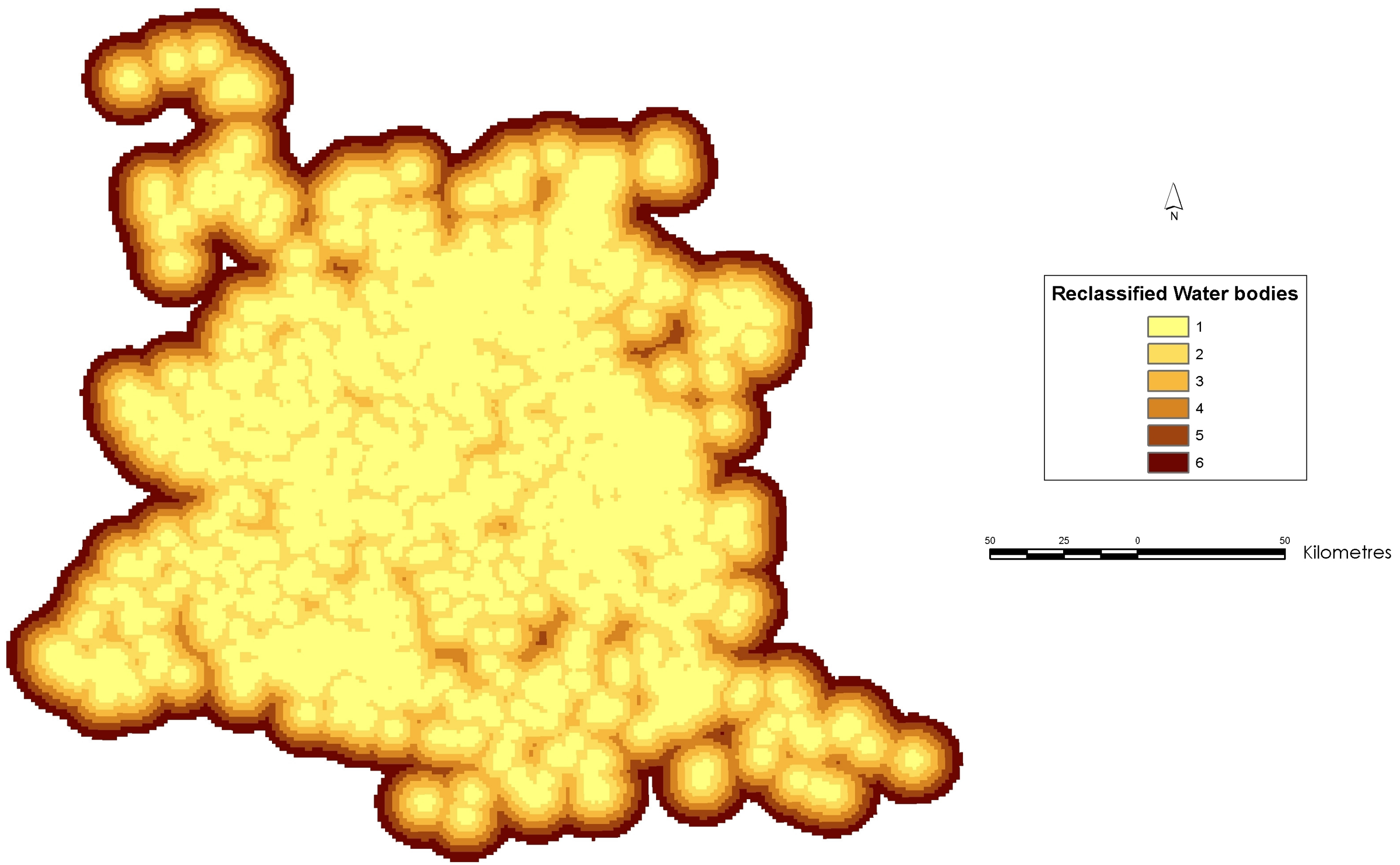

Figure 4: Reclassified Water bodies, where 6 represents the most suitable and 1 represents the least suitable site.

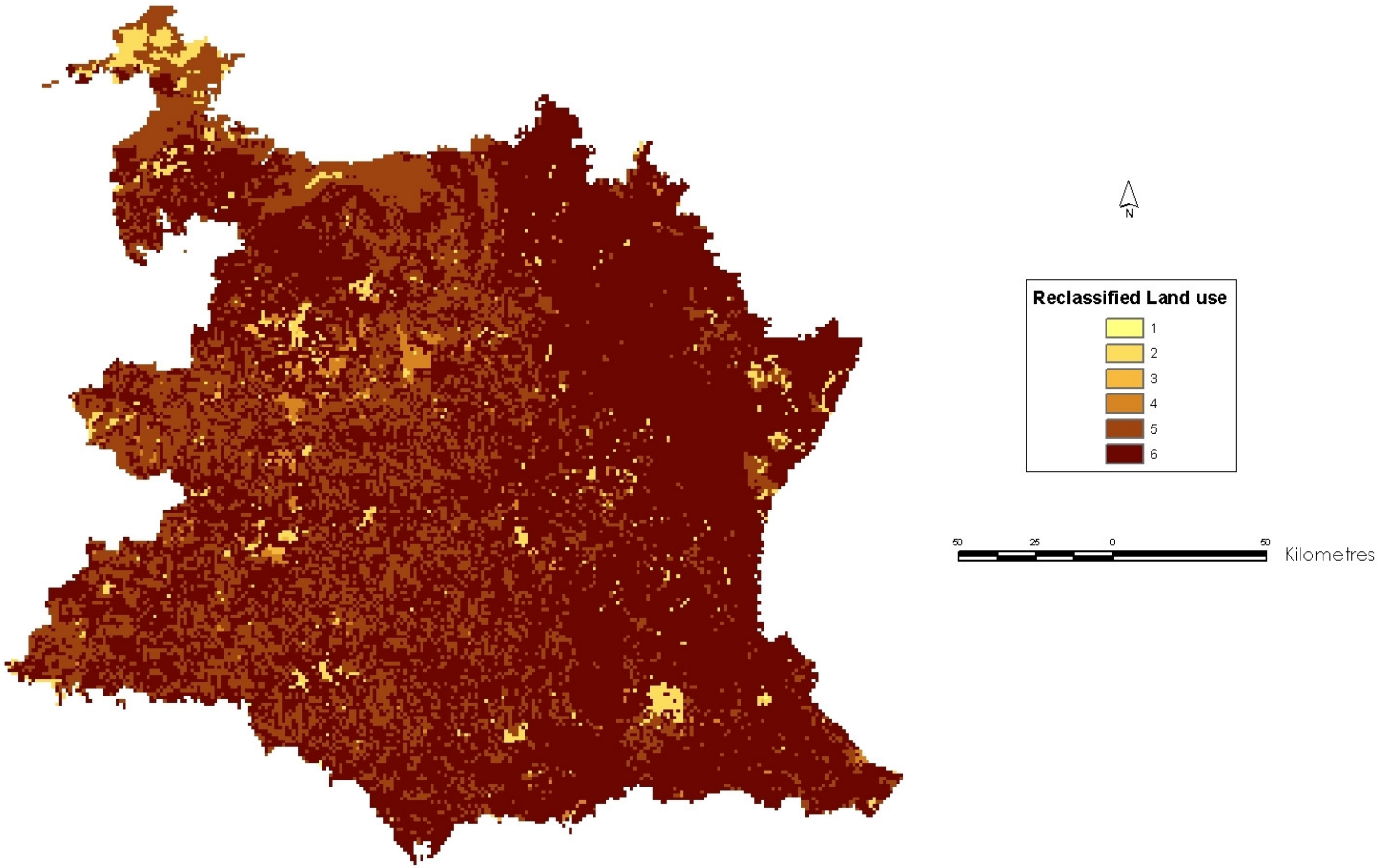

Figure 5: Reclassified Land use, where 6 represents the most suitable and 1 represents the least suitable site.

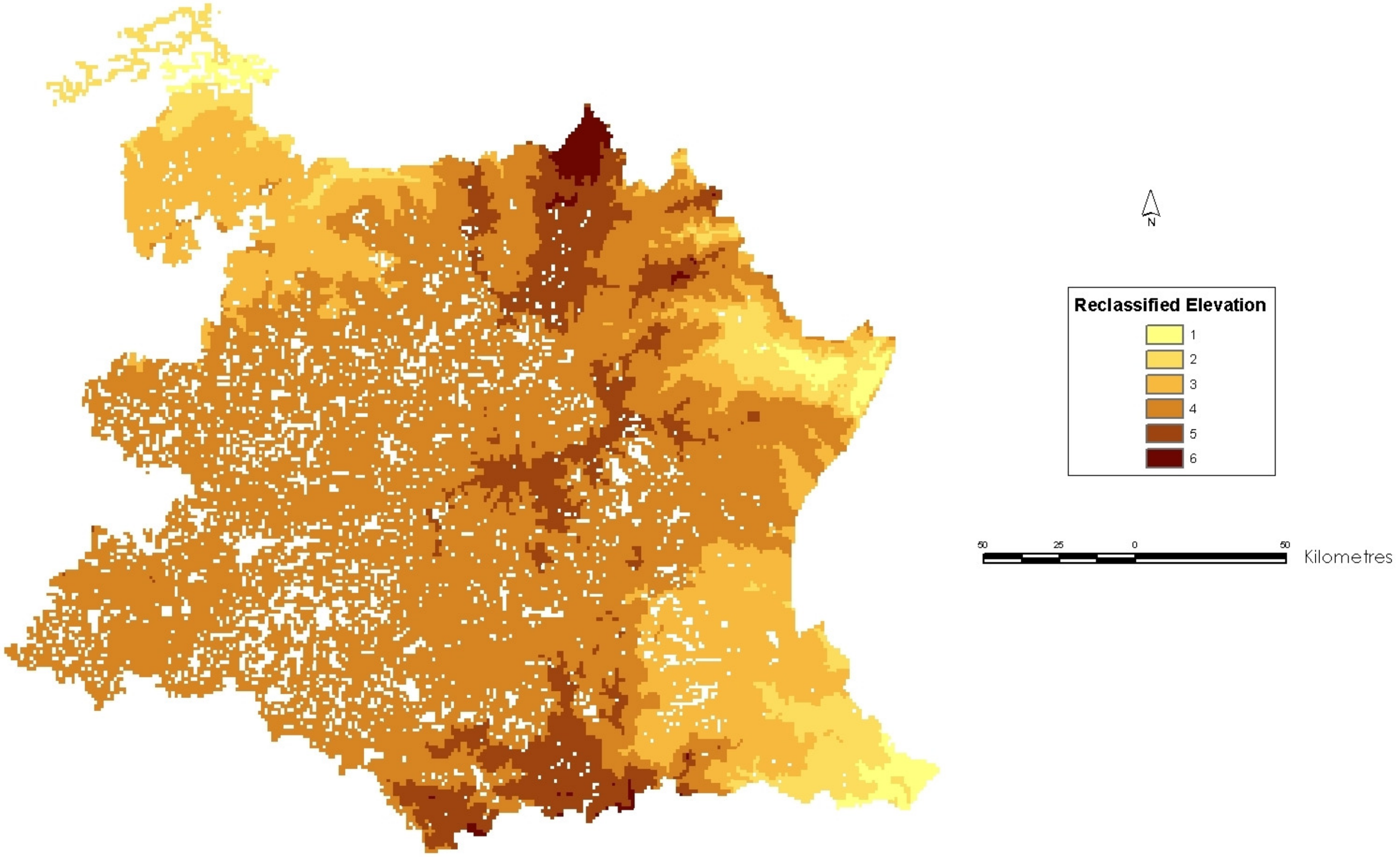

Figure 6: Reclassified Elevation, where 6 represents the most suitable and 1 represents the least suitable site.

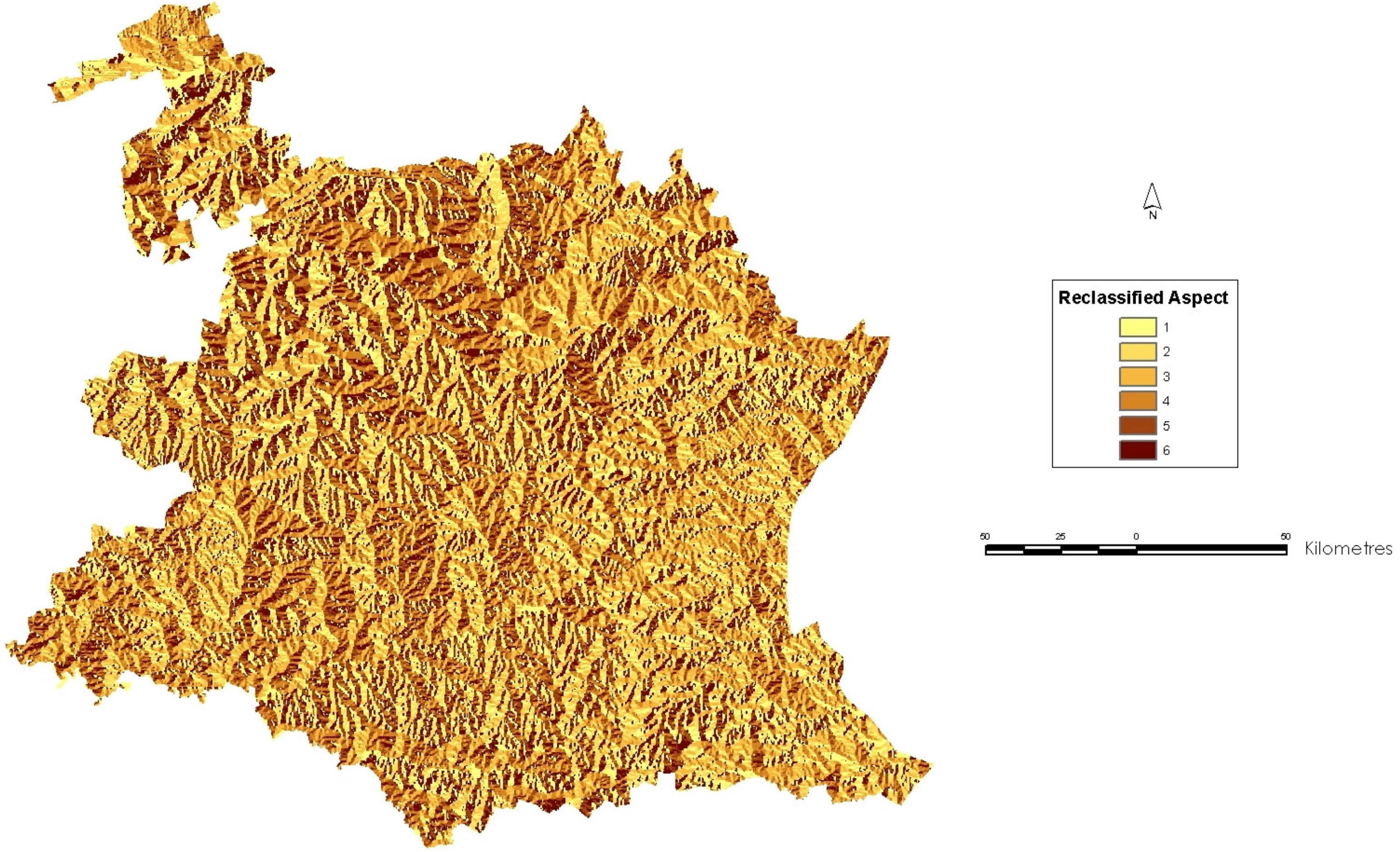

Figure 7: Reclassified Aspect, where 6 represents the most suitable and 1 represents the least suitable site.

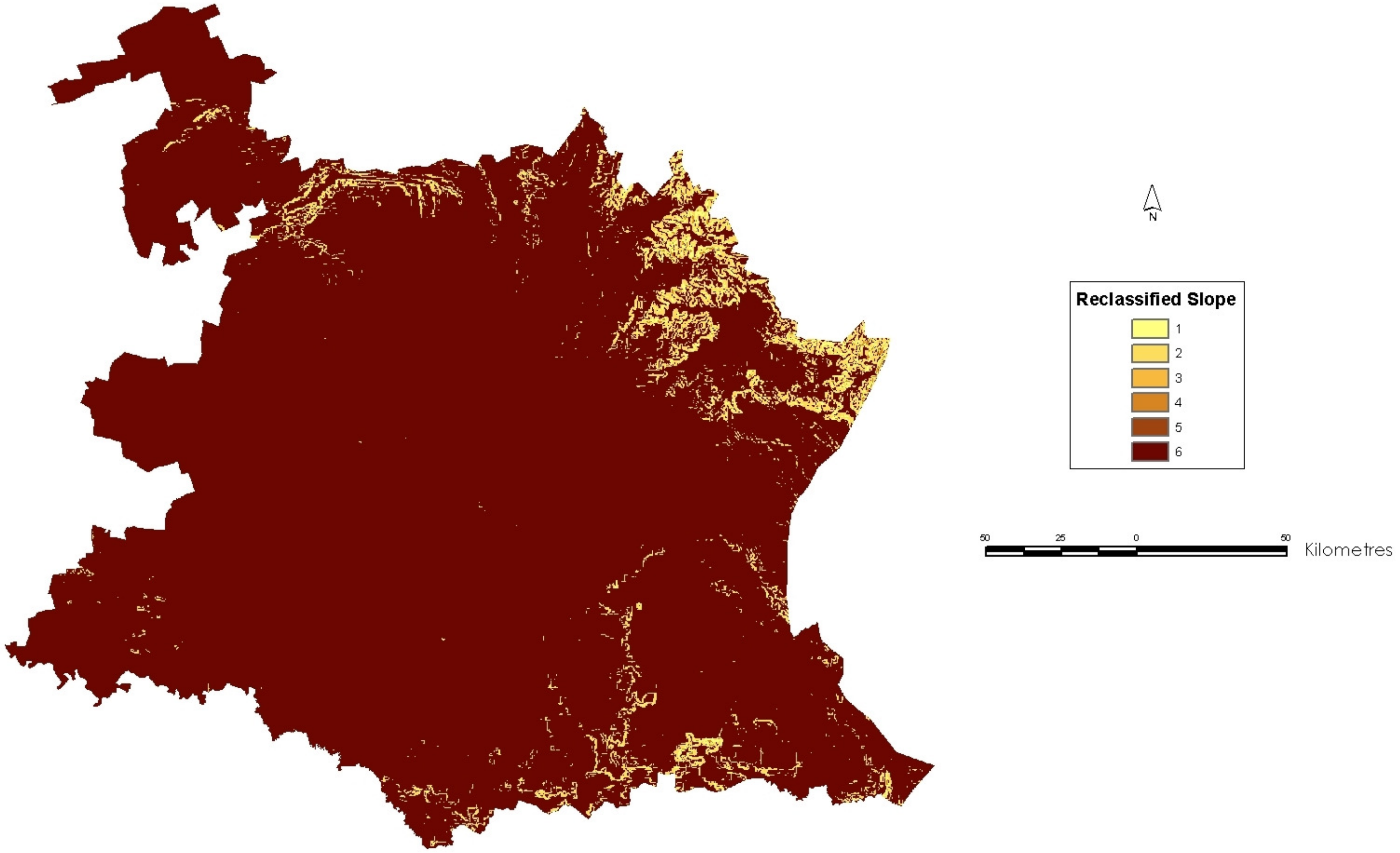

Figure 8: Reclassified Slopes, where 6 represents the most suitable and 1 represents the least suitable site.

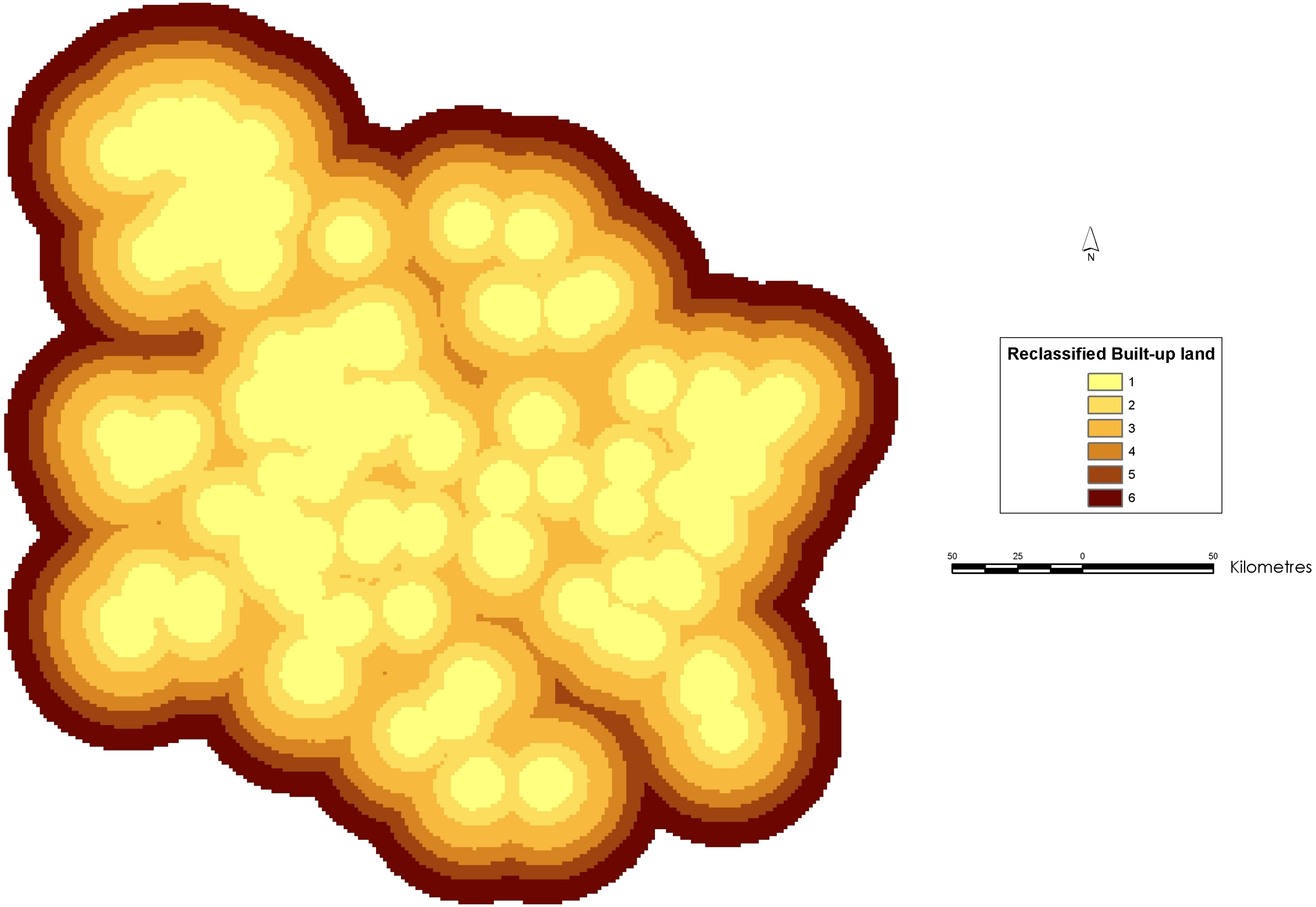

Figure 9: Reclassified Built-up land where 6 represents the most suitable and 1 represents the least suitable site.

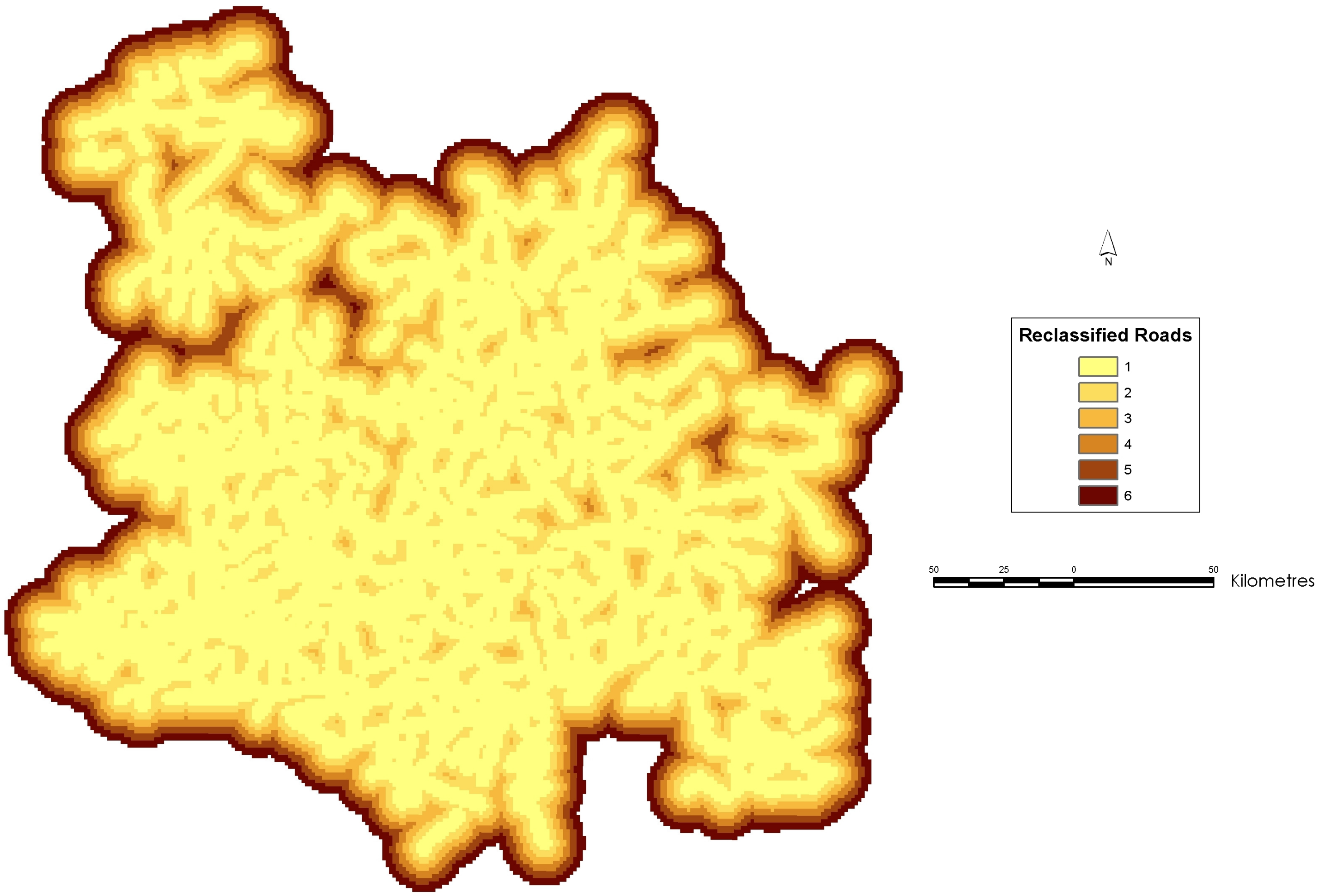

Figure 10: Reclassified Roads, where 6 represents the most suitable and 1 represents the least suitable site.

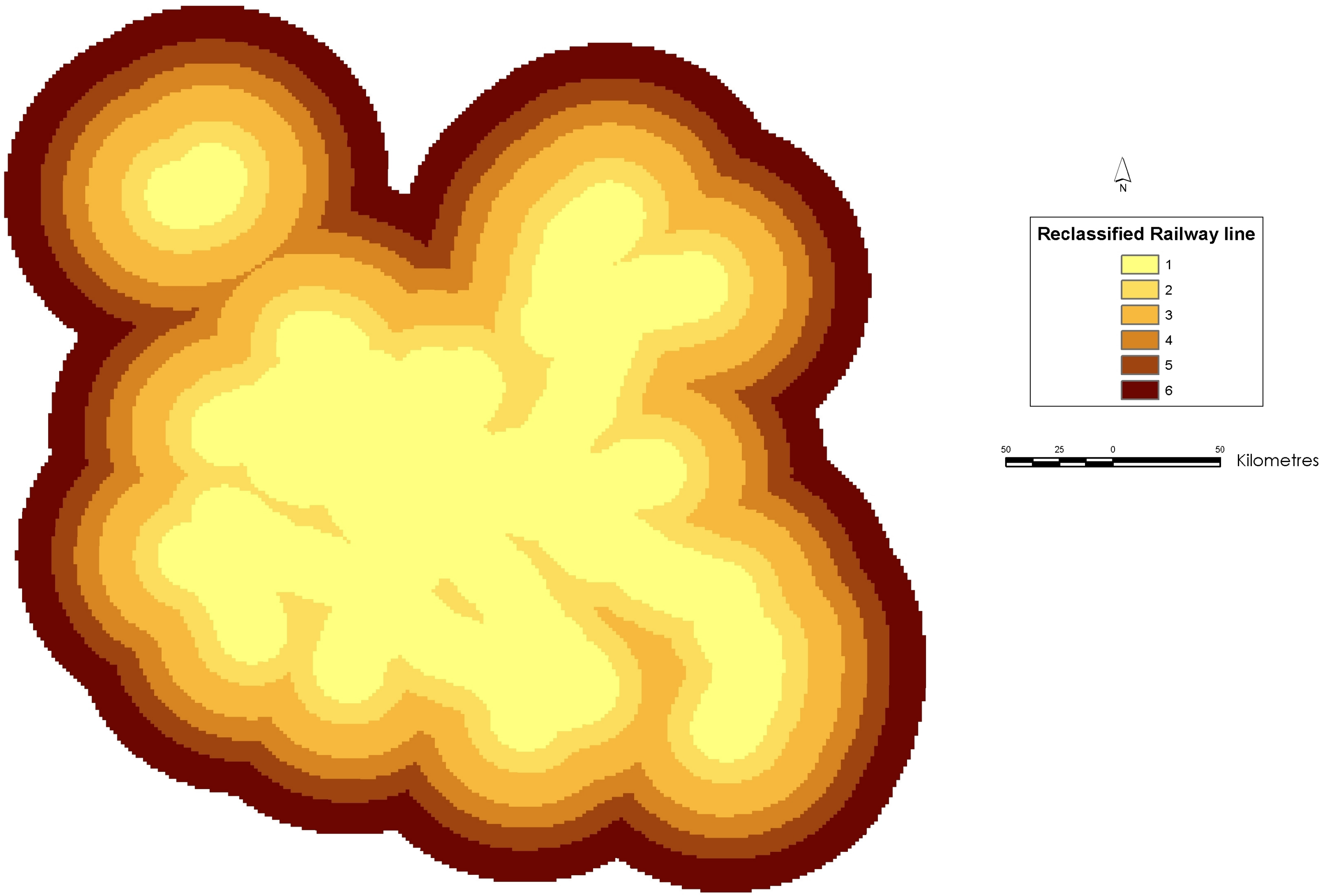

Figure 11: Reclassified Railway line, where 6 represents the most suitable and 1 represents the least suitable site.

Figure 12: Flow chart representing habitat suitability model.

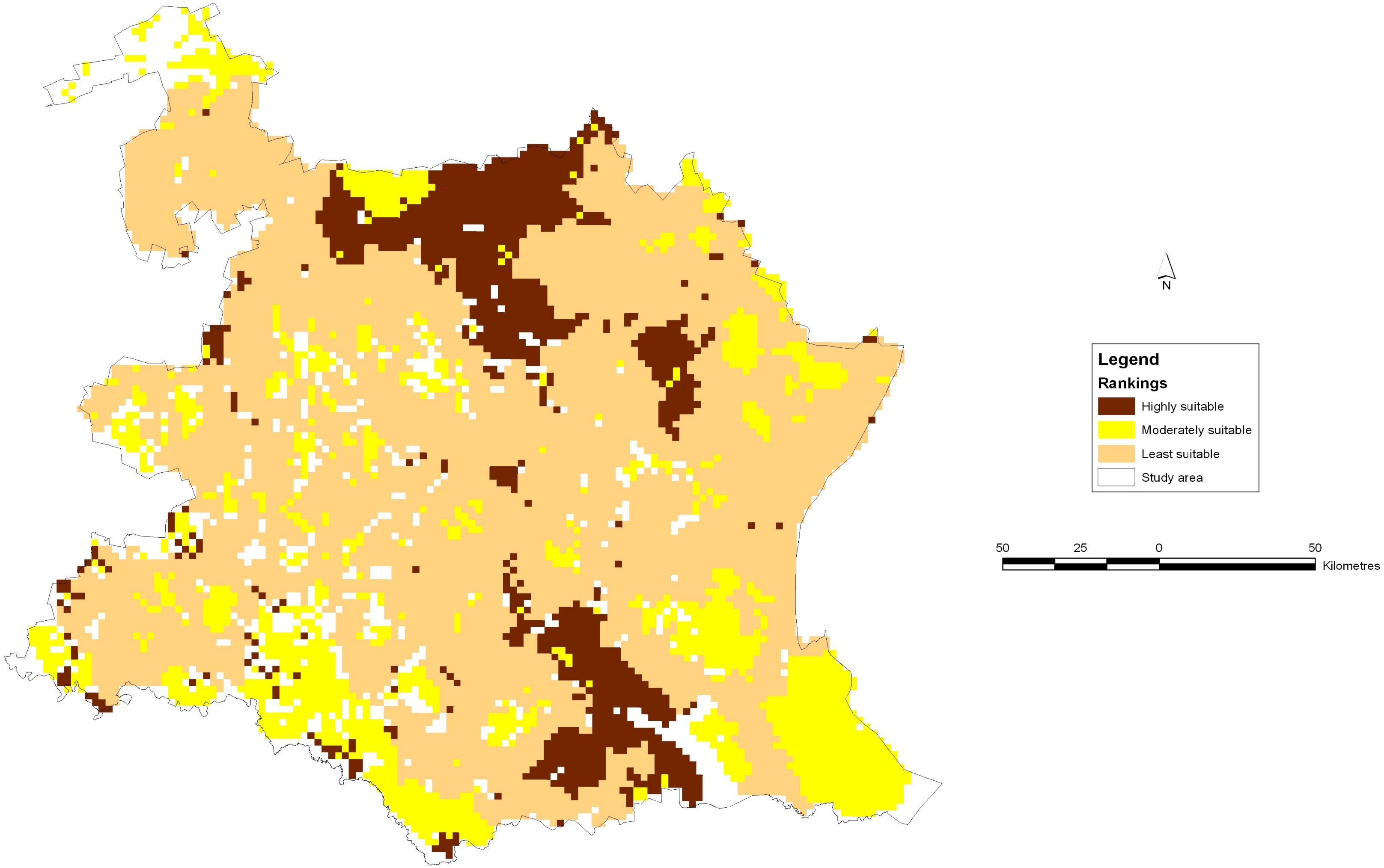

Figure 13: Breeding habitat suitability map.

### 4.4 RESULTS

The interpretations of the model presented here is limited to variables and parameters used during this study. Highly suitable sites were in a fragmented form and appeared mainly in the northern and southern part of the study area (Figure 13). The potential sites were categorised into highly, moderately and least suitable areas (Figure 13). Highly suitable areas accounted for 601, 448 ha, while moderately suitable areas accounted for 825,593 ha, and least suitable areas covered 3, 000, 153 ha in a study area covering 4, 861, 139 ha. The restricted sites and areas that fell below the three ranking levels used in this study, make up an average of 433, 944 ha of remaining land within the study area.

### 4.5 DISCUSSION AND CONCLUSIONS

Nine habitat variables were used to construct what constituted the first study of GIS-based habitat suitability of the Blue Cranes. Analytic Hierarchy Process scale of comparison was used to weigh variables based on their influence on the breeding activity of Blue Cranes. The scope of this study was constrained within the boundaries of two municipalities, however, the framework of the model created, provides a valuable tool for protection of this species in other areas of its range. The model produced here was not validated in the field. Although, model evaluation is highly significant; Larson *et al.* (2003) makes an assumption that habitat suitability models, even if not validated, are a useful method to synthesize and apply current knowledge of habitat relationships to management or conservation questions.

One of the challenges of constructing habitat suitability models is assigning weights to variables. During model construction, variables should be assigned weights based on their influence to the given species. For example, in the current study, variables (vegetation, water sources, land use, elevation, slope, aspect, built-up land, roads and railway line), were assigned weights based on their influence on the breeding activity of the Blue Cranes. Choosing important variables and their weights should be based on a careful review of existing knowledge of the particular species and habitat. However, variables were chosen based on available literature and other sources of the breeding ecology, while the subjectivity related to weighting of variables were minimised through the use of AHP method.

When reclassifying categorical variables such as vegetation and land use, a challenge emanate when unrelated data gets classified together. However, the same challenge is not necessary a problem when dealing with continuous data such as built-up land, roads, and railway line).

One of the advantages of using habitat suitability model is that they can be edited and modified as new data becomes available. All the processes used in both spatial modelling and analytical analysis are closely outlined, making the process repeatable. The model is systematic and it may be adapted and used to analyze similar situations. Thus, continual collection of data will be beneficial as new information can be incorporated into the model.

## 4.6 REFERENCES

ALLAN, D.G. 1994. Haven for Blue Cranes. *African Wildlife 48 (4): 8-14.*

BIDWELL, M.T. 2004. Breeding habitat selection and reproductive success of Blue Cranes Anthropoides paradiseus in an Agricultural Landscape of the Western Cape. MSc dissertation, University of Western Cape.

BURNSIDE, N., SMITH, R. & WAITE, S. 2002. Habitat suitability modelling for calcareous grassland restoration on the South Downs, United Kingdom. *Journal of Environmental Management 56: 209-221.*

DAI, F.C., LEE, C.F. & ZHANG, X.H. 2001. GIS-based geo-environmental evaluation for urban land use planning: a case study. *Engineering Geology 61: 257-271.*

DESBIEZ, A.L.J., BODMER, R.E. & SANTOS, S.A. 2009. Wildlife habitat selection and sustainable resources management in a Neotropical wetland. *International Journal of Biodiversity and Conservation 1(1): 11-20.*

FORMAN, E. & GASS, S.I. 2001. The Analytic Hierarchy Process: An exposition. *Operations Research 49(4): 469-486.*

GOLDEN, B.L., WASIL, E.A. & HARKER, P.T. (Eds) 1989. The Analytic Hierarchy Process: Applications and Studies. Springer-Verlag, New York.

GOLDEN, B. & WASIL, E.A. 2003. Celebrating 25 years of AHP-based decision making. *Computers and Operations Research 30(10): 1419-1497.*

GOUGH, M.C. & RUSHTON, S.P. 2000. The application of GIS-modelling to mustelid landscape ecology. *Mammal Review 30(3): 197-216.*

GRINNEL, J. 1917. Field tests of theories concerning distributional control. *American Naturalist 51: 115-128*.

HARVEY, D.S. & WEATHERHEAD, P.J. 2006. A test of the hierarchical model of habitat selection using eastern massasauga Rattlesnake. *Biological Conservation 130: 206-216.*

LARSON, M.L., DIJAK, W.D., THOMPSON, F.R. & MILLSPAUGH, J.J. 2003. Landscape-level habitat suitability models for twelve wildlife species in southern Missouri. General Technical Report. St. Paul, MN, USDA.

LI, X., LI, D., LI, Y., LI, Z., MA, Z. & ZHAI, T. 2002. Habitat evaluation for the crested ibis: A GIS-based approach. *Ecological Research 17: 565-573.*

MCCANN, K. 2000. The crane train – a journey of conservation discovery. Vision of wildlife, ecotourism and the environment. Endangered Wildlife Trust. Johannesburg.

MCCANN, K., MORRISON, K., BYERS, A., MILLER, P. & FRIEDMANN, Y. (Eds) 2001. Blue Crane Anthropoides paradiseus: A Population and Habitat Viability Assessment Workshop. Conservation Breeding Specialist Group (SSC\IUCN). Apple Valley, MN.

MCGREGOR, S. 1998. An integrated Geographic Information System approach for modelling the suitability of Conifer habitat in an Alpine Environment. *Geomorphology 21: 265-280.*

MORRISON, K.L. 1998. Habitat utilization and the population ecology of cranes in the Dullstroom area of the Mpumalanga Province. MSc dissertation, University of Pretoria.

PEREIRA, J.M.C. & ITAMI, R.M. 1991. GIS-based Habitat Modeling Using Logistic Multiple Regression: A Study of the Mt. Graham Red Squirrel. *Photogrammetric Engineering and Remote Sensing 57: 1475-1486.*

SAATY, T.L. 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology 15: 231-281.*

SAATY, T.L. 1980. The Analytic Hierarchy Process, McGraw-Hill, New York.

SAATY, T.L. 2000. Fundamentals of the Analytic Hierarchy Process. RWS Publications, Pittsburg.

SAATY, T.L. & VARGAS, L.G. 1991. Prediction, projection and forecasting. Kluwer Academic Publisher, Dordrecht.

SHIM, J.P. 1989. Bibliography research on the Analytic Hierarchy Process (AHP). *Socio-Economic Planning Sciences 23(3): 161-167.*

UNITED STATES FISH AND WILDLIFE SERVICE. 1981. Standards for the development of habitat suitability index models, Ecological Service Manual 103, Washington.

VARGAS, L.G. 1990. An overview of the Analytic Hierarchy Process and its applications. *European Journal of Operational Research 48(1): 2-8.*

ZARRI, A.A., RAHMANI, A.R., SINGH, A. & KUSHWAHA, S.P.S. 2008. Habitat suitability assessment for the endangered Nilgiri Laughingthrush: A multiple logistic regression approach.

# CHAPTER 5

# GENERAL DISCUSSION AND CONCLUSION

### 5.1 INTRODUCTION

This study investigated three main topics (home range, habitat selection and habitat suitability) related to the breeding ecology of Blue Crane. Appropriate tools and techniques were used to meet the objectives of each topic. It is also acknowledged that the main objectives were achieved although there were some limitations. The main limitation of this study was lack of adequate data (i.e., the sample size used in analysing home ranges was very small).

### 5.2 THE USE OF GIS IN WILDLIFE CONSERVATION

The GIS technology proved to be vital in this study. That was evident from the ease of this technology in capturing, manipulating, analysing and presentation of the results. It should however be noted that the utilization of GIS relies mostly on the data used during analysis. GIS capabilities were also shown in the ability to integrate data captured from various sources using different methods such as a GPS receiver for data collection and Remote Sensing for handling satellite imagery. Again, the usefulness of GIS was also shown through the ability to integrate extensions such as ModelBuilder, spatial analyst and home range extension.

To summarize, although there is improvement in geo technological advances, the most common disadvantage is that most available wildlife data is not enough to be used without prior check-up. Thus, before any analysis, it is recommendable to: (1) assess the reliability of the biological data for the species, (2) compile and analyze the existing information to identify areas with reliable inventories, and, eventually, (3) design and run a survey to optimize the coverage of data on biodiversity patterns. These steps will enhance the integrity of GIS produced outputs. A good use of biodiversity data will come only by assessing the reliability of data and accounting for its actual quality and accuracy. If the weaknesses of data are previously known and their analysis takes these drawbacks honestly into account, the conclusions gathered will be robust.

### 5.3 HOME RANGE

The main objective of this part of the study was to determine home range sizes of the Blue Crane during the breeding season. This objective was met although with the main limitation of small sample size. The use of GIS also proved useful in capturing, storing, manipulation and analysis of the data. Fixes were captured using a GPS in the field, and the data was then prepared in Excel before being imported into the GIS system. Home range sizes were delineated successfully. It is believed that this part of the study could have produced more ecologically meaningful results if the habitat variables and activities were recorded at each location where the birds were observed.

### 5.4 HABITAT SELECTION

The main objective was to determine habitat selection by the Blue Crane during breeding. Again, the use of GIS proved significant in analysis of species habitat variables. Habitat selection part produced results that are similar to other studies. The environmental, physiographic and anthropogenic variables studied here, had an influence on nest sighting by Blue Cranes.

### 5.5 HABITAT SUITABILTIY

The objective was to construct a habitat suitability model for the Blue Crane breeding sites. This represents the first study of habitat suitability for these birds. It is therefore, assumed that future studies can draw from some of the findings from this project. Maps showing habitat suitability can provide a strong foundation for applied research and conservation planning (Graham and Hijmans, 2006). However, these maps are only as effective as the data and methods used to create them. It must, however, be noted that no model can replace extensive field-based surveys of any species. Models are best used as approximations of the truth to help guide researchers in the field who can report back and incorporate new findings to refine models. The prediction model is highly recommended for wildlife conservation, where the increase or decline of species indicates a specific change in the balance of the environmental factors of that area. By using this method, such changes can be identified and managed. Once spatial distribution is effectively modelled, distribution and abundance may be successfully predicted by keeping track of key factors' change in order to manage the area of concern toward a sustainable system.

## 5.6 RECOMMENDATIONS

An array of additional data and techniques could be used to improve the results obtained in this study. For example, using techniques such radio telemetry to monitor the birds during breeding will enable researchers to have a better understanding of the movement. With data from radio telemetry, it will be easier for researchers to investigate resources and activity at each location with good accuracy. Those results can in turn be used in habitat suitability models. Ground-truthing exercise could also be used to substantiate the results. Despite the limitations, it is anticipated that this study will form the basis from which future studies can draw from.

Using GIS technology to create a data bank for all animal species at a national level, and updating it regularly upon yearly reports, the current knowledge will be greatly enhanced (making improvements on Blue Crane data collection such as movement data, and habitat variable use, may aid conservation efforts). In turn, that will improve the modelling accuracy of wildlife distribution. However, lack of reliable and complete data on certain species is still the limiting factor in many instances (Gurnell *et al*., 2002). A clear example of this is lack of locations on breeding pairs prior to the start of this study.

## 5.7 REFERENCES

GURNELL, J., CLARK, M.J., LURZ, P.W.W., SHIRLEY, M.D.F. & RUSHTON, S.P. 2002. Conserving Red Squirrels (Sciurus vulgaris): Mapping and forecasting habitat suitability using a Geographic Information Systems Approach. *Biological Conservation 105: 53-64*.

GRAHAM, C.H. & HIJMANS, R.J. 2006. A comparison of methods for mapping species ranges and species richness. *Global Ecology and Biogeography 15: 578-587*.