THE USE OF A GEOGRAPHIC INFORMATION SYSTEM TO INVESTIGATE THE EFFECT OF LAND-USE CHANGE ON WATTLED CRANE *Bugeranus carunculatus* BREEDING PRODUCTIVITY IN KWAZULU-NATAL, SOUTH AFRICA.

by

BRENT MILES COVERDALE

Submitted as the dissertation component in partial fulfilment of the requirements for the degree Master of Environment and Development in the Centre for Environment, Agriculture and Development, University of KwaZulu-Natal, Pietermaritzburg.

JULY 2006

"The fate of birds, mammals, frogs, fish and all the rest of biodiversity depends not so much on what happens in parks but what happens where we live, work, and obtain the wherewithal for our daily lives. To give biodiversity and wildlands breathing space, we must reduce the size of our own imprint on the planet."
John Tuxill (1998: 72)

PREFACE

The work described in this dissertation was carried out in the Centre for Environment, Agriculture and Development, University of KwaZulu-Natal, Pietermaritzburg, from September 2003 to November 2005, under the supervision of Prof T. Hill (Discipline of Geography) and K.I. McCann (Endangered Wildlife Trust). The format adopted for this dissertation departs from the conventional style, in that it is presented as two separate components, Component A, comprising an Introduction, Literature review and description of Methods, whilst Component B is submitted in the form of an academic paper, to be published in the Journal of Agriculture, Ecosystems and Environment.

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any other University. Where use has been made of the work of others this is duly acknowledged. Portions of this work include intellectual property of the CSIR/Agricultural research Council and are used herein by permission.

Signed: ____________________

B.M. Coverdale

25th July 2006

Supervisor

Signed: ____________________ and ____________________

T. Hill — K.I. McCann

25th July 2006 — 25th July 2006

ABSTRACT

The Wattled Crane, *Bugeranus carunculatus* Gmelin, is presently classified as being 'Critically Endangered' within South Africa according to the Eskom Red Data book of Birds of South Africa, Lesotho and Swaziland, with a population of a meagre 235 individuals. Of this, 85% occur within KwaZulu-Natal and live predominantly on privately owned agricultural land. As a result thereof, Wattled Cranes and agriculture compete for the same resources. Up until now, the loss of viable habitat, as a result of agricultural development and afforestation, has been mooted as being the primary reason for the decline in numbers of the species. The advancements in the Geographical Information Systems field have enabled conservationists to acquire data, especially pertaining to habitat requirements, which were previously unattainable. This improved data acquisition is enabling for more informed decision making and better allocation of resources. The study therefore attempts to make use of a Geographical Information System to determine whether or not differences exist within the home ranges of active and historical Wattled Crane nesting sites, utilising the National Land cover database.

The updated Land cover data for South Africa, although not completed at the time the present study took place, allowed for the interrogation of the various Land cover classes within an estimated home range. Natural Grassland was the predominant Land cover type within both active and historical home ranges, whilst both active and historical home ranges were subject to some degree of transformation. The potential impact of management practices in and around nesting sites warrants further investigation because this could not be determined through the analysis of land cover.

ACKNOWLEDGEMENTS

I have many people and organisations to thank, to whom I am immensely grateful and without whose help this study would not have been possible:

The KwaZulu-Natal Crane Foundation for affording me the opportunity to further my studies and allowing me to spend time away from work.

Dr Trevor Hill (Discipline of Geography) for being an understanding supervisor, being flexible regarding deadlines and for his encouragement and support.

Kevin McCann (Endangered Wildlife Trust) for sharing his vast knowledge on cranes, much of which knowledge is not to be found in the literature and for always being willing to listen to my complaining regarding the loss of grasslands.

The Council for Scientific and Industrial Research (CSIR), for allowing me to utilise the NLC2000 data before the project had been completed.

Ezemvelo KZN Wildlife for agreeing to provide me with the NLC 2000 data on behalf of the CSIR.

Craig Morris (Agricultural Research Council-Range and Forage Institute), for helping me understand statistics.

My mother, for her support and encouragement to get my Masters degree done.

Finally, to my darling wife, Faye, for being so understanding whenever I had to work and was not able to spend time with her. A big thank you.

Table of Contents

LIST OF PLATES, TABLES AND FIGURES

PLATES

FIGURES

TABLES

1. INTRODUCTION

1.1 INTRODUCTION

The crane family is amongst the most ancient of all avian families, and it occurs on all but two of the earth's continents. Cranes have long been recognised for their cultural significance and over the millennia have adapted to life in wetlands and grasslands, co-existing with human populations (Harris 1994). However, the burgeoning human population and associated land use changes now pose a serious threat to the cranes' existence and, combined with continued resource consumption and exploitation, indiscriminate hunting and habitat destruction, seven of the 15 species of cranes across the globe face the very real threat of extinction, with the remaining eight species declining at an alarming rate.

Cranes and people have had a long and complex relationship, with the cultural significance of cranes being rich and varied. However, now more than ever, these interactions have reached a crossroads. As conservationists and scientists knowledge of cranes and their requirements increases, the human population and its demand on the earth's resources is increasing and as a consequence crane numbers are declining. The threats presently facing cranes are synonymous with biodiversity decline in general. As migratory vertebrates, cranes provide an appropriate justification for the protection of aquatic habitats and for a wider array of species (Haney & Eiswerth 1992) and thus conservation of cranes is of paramount importance in global efforts to conserve the earth's ever dwindling biodiversity. Cranes, and in particular the Wattled Crane (*Bugeranus carunculatus*), are indicator species for the world's threatened wetland ecosystems. The decline in numbers of the Wattled Crane within South Africa is ultimately as a result of the continued degradation of the country's wetland ecosystems: the same such systems that mankind is reliant upon for the provision of clean water, flood attenuation and the prevention of soil erosion.

1.2 HUMAN IMPACTS UPON THE ENVIRONMENT AND THE DECLINE OF BIODIVERSITY

Human alteration of the earth is substantial and is proceeding on a daily basis. It is suggested that between one third and one half of the earth's land surface has already been transformed by human action (Vitousek, Mooney, Lubchenco & Melillo 1997). Such manipulation of the physical environment through engineering and other man made structures has reached threatening proportions. The overconfidence of mankind's ability to manage the physical environment has left a legacy of large dams, channelled rivers, degraded wetlands and stabilised shorelines, all of which have severe consequences for the natural environment. The resultant impact is that some environments have been substantially lost or severely degraded (Warren & French 2001). Mankind's preoccupation with managing the physical environment combined with the transformation of natural vegetation as a result of crop cultivation, stock farming, afforestation and urban development presents the single greatest threat to global biodiversity (Ratcliffe & Crowe 2001). The earth's ever decreasing assemblage of, and accelerated decline, in biodiversity have been the recipient of much attention over the last decade. Numerous organisations have published data highlighting that the extinction rates of plants and animals are a thousand times the natural rate and that humankind is presently experiencing the phenomenon dubbed the 'sixth extinction' (Haney & Eiswerth 1992; Tekelenburg, Prydatko, Alkemade, Schaub, Luhmann & Meijer undated). Extinction is the final process within a long and complex process of ecosystem degradation, which process is characterised by the decline of the abundance and distribution of many species and by the concurrent increase in abundance and distribution of a few others. The dilemma that conservationists thus face, in this age of limited resources and competition for funding, is to ensure that a suitable array of species and habitats are conserved whilst simultaneously trying to avoid bias towards one or another species or habitat.

Historically, the predominant focus of conservation efforts has been to secure suitably sized tracts of land and then to proclaim such tracts of land as protected areas of varying categories. This it was thought would ensure the protection of large, undisturbed and model ecosystems as well as would afford protection to the species and populations therein with a special emphasis on the preservation of rarity and uniqueness. Despite this approach, biodiversity still remains under represented and under protected within these protected areas. This approach to conservation has not only led to under representation of biodiveristy but it has also meant that there has been an increase in pressure on the existing resources outside of these designated areas and as a consequence biodiversity, outside of protected areas, is under threat. This approach has also failed to compete for funding successfully with needs such as employment opportunity, standard of living and economic development (Finlayson & Moser 1991; Gall & Orions 1992; Halladay & Gilmour 1995). Yet, it is within these areas outside formally protected areas that 95% of all crane populations occur within South Africa and hence the reason behind the concerted efforts to protect this species.

Agriculture, since its inception some ten thousand years ago, has become the dominant form of land management worldwide. It has not been until recently that agriculture has become of concern to conservationists with the emergence of widespread publications highlighting the adverse affects of agricultural practices upon the environment. This has resulted in much antagonism between farmers and conservationists (Gall & Orions 1992). However, the agricultural impact upon the environment is dependant to a greater degree on the farmer and his production practices rather than the agricultural practice alone. Farmers and agricultural producers have, and are, responding to global market forces and are specialising in fewer, more intensive crops that provide even the slightest advantage in an ever increasing competitive market. This has resulted in the decline of nitrogen fixing bacteria, predators, pollinators, seed dispersers and other organisms which have co-evolved over centuries with traditional agricultural systems. This loss is exacerbated with the increased usage of fertilizers, pesticides and high-yield varieties of crops to maximise production and profits over the short-term with little or no regard to the long-term effect (McNeely 1995). The human population is growing at an ever increasing rate and thereby increasing the demand for food production and as a result placing greater pressure on the limited resources outside protected areas. It is therefore imperative that careful management of the land is instituted not only to ensure that it remains a sustainable basic resource but also to conserve the biodiversity, of which cranes are an important component, on such land (Rivers-Moore 1997).

1.3 ECOLOGY OF CRANES

Cranes prefer large open spaces, and require territories with a wide range of visibility. The space and solitude that such areas afford is of paramount importance during the breeding season, because cranes are especially susceptible to disturbance at this time. Most crane species will nest in the shallows of wetlands, where both their feeding and breeding requirements are met (Del Hoyo 1992). However, wetlands are not isolated systems and are reliant on the surrounding habitat to function effectively and thus the management of the surrounding habitat is as imperative as that of the wetland itself.

Cranes present an exemplary case for biodiversity conservation in as much as they are firstly a charismatic species, secondly they are a migratory species providing good justification for the protection of aquatic habitats and a host of other species, thirdly, they are widely distributed across the globe, fourthly, they have been the subject of numerous research projects and lastly, seven of the 15 species are either threatened, endangered or considered to be at some risk (Haney & Eiswerth 1992). It is the loss of grassland and wetland habitats, through agricultural development and human expansion, that has been the leading factor in the decline of cranes. The fragmentation of such habitats, as a result of human activities, has resulted in the decline of numerous bird species, the Wattled Crane included (Newton 1998; Ratcliffe & Crowe 2001). Ironically, it is the same such systems that mankind is dependant upon for its survival and the destruction of which has meant that cranes have come into direct conflict with mankind in the remaining grassland and wetland areas. This destruction of habitat, which has ultimately led to the decline of numerous other crane species, has also affected the Wattled Crane. The subsequent low population numbers of the Wattled Crane justify the current conservation initiatives and the need to quantify the extent of habitat transformation.

1.3.1 Wattled Crane Conservation

The Wattled Crane *Bugeranus carunculatus* Gmelin, is presently classified as 'Critically Endangered' within South Africa, in the latest Eskom Red Data Book (Barnes 2000). Its population, a meagre 235 individuals, of which 85% occur within KwaZulu-Natal (KZN), reside predominantly on privately owned agricultural land (McCann & Benn *in press*). The Wattled Crane is a species highly dependant on wetlands, and as such is sensitive to wetland quality deterioration and therefore acts as a flagship species for wetland conservation. Wetlands are primarily water managers and as such play a pivotal role in the provision of water, especially in a dry country such as South Africa. Wetlands provide a wide array of functions which include the following:

- Regulation of water flow during flood periods thereby reducing flood damage,
- Prevention of soil erosion,

- Purification of water, action as filtration systems and trapping pollutants, especially heavy metals and disease causing bacteria and viruses.

(Mondi Wetland Project 2000)

Thus, it is imperative that wetlands are protected in order to provide healthy water for human consumption. Wetlands are, however, not stand alone systems and are reliant upon the surrounding habitats, for effective functioning. The degradation of the surrounding habitat can thus have a severe impact on wetlands' functioning and thereby ultimately impact upon mankind (Dickens, Kotze, Mashigo, MacKay & Graham 2003). The Wattled Crane can act as an early indicator of wetland degradation as a result of their dependency and susceptibility to wetland deterioration. These wetland-dependant species indicate the health of South Africa's diminished wetland systems, these same systems that are vital for mankind's existence because they perform numerous ecological functions (Kotze & Breen 1994). Therefore, ensuring the conservation of the Wattled Crane can contribute to the protection of the country's water resources (McCann 2002).

Barlowe (1978) identifies a threefold framework that land use practices must operate within, namely: an ecological practicability (suitable soils, water availability etc.), economic feasibility (input-output relation) and the institutional acceptability (legislation compliance). Yet, the present economic 'drivers' of agriculture dictate that intensification of viable areas is essential in order for the enterprisers of landowners to remain economically viable and as such, economics has become the major driving factor in land use practices within South Africa. This has resulted in large tracts of pristine grasslands being transformed into a myriad of potato, maize, rye grass and afforested areas, specifically in and around Wattled Crane home ranges. Accompanying the transformation of grassland are the impacts upon the wetland systems through increased disturbance, sedimentation and management practices (burning and grazing). The present consensus regarding these impacts with respect to specifically Wattled Cranes is that they are negatively impacting upon the breeding productivity of the remaining 65 breeding pairs in KZN and that the marked decline in the breeding success of Wattled Cranes over the past two decades has been as a direct result of the change in land use and accompanying management practices (Ronchini 1998; McCann 2002; McCann & Benn *in press*). This decline in breeding productivity has resulted in fewer fledglings each year contributing to the overall population. Compounding the problem of decreased fledgling success are the other threats that cranes presently face, namely: power line collisions, poisonings, fences and direct persecution in and around breeding sites. The management of these breeding areas is thus critical and therefore a set of credible management guidelines needs to be compiled through analysis of present management practices and their relation to breeding of cranes.

1.4 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is threefold: firstly utilising updated land cover data, through the National Land Cover Project 2000, courtesy of the Council for Scientific and Industrial Research (CSIR), to determine whether the land cover composition surrounding Wattled Crane nest sites can lead to the abandonment of nest sites, secondly, utilising spatially referenced data, to ascertain whether a relation exists between land use (in its broad scale under the National Land Cover Project) and the breeding productivity of Wattled Cranes, and thirdly to ascertain whether the configuration of the landscape within the home range will influence site selection.

To meet the aim of the study, numerous objectives were set. These objectives are as follows:

- To provide a review of available literature on Wattled Cranes, Geographical Information Systems incorporating land cover and land use and the interaction between agriculture and conservation,
- To determine whether there are differences in land cover types surrounding active and abandoned Wattled Crane nest sites,
- To determine whether there are differences in productivity of active breeding sites and whether there are differences in land cover surrounding these sites,
- To determine whether the patch make-up of the land cover differs between active and historic sites and if such patch make-up can determine site selection,
- To determine whether there are any differences in the management of the areas surrounding Wattled Crane nest sites: both active and historical sites as well as wetlands not yet utilised, and
- To formulate a set of acceptable land use practices and management guidelines to encourage increased productivity at breeding sites.

This study is not intended to criticise the agricultural community that dominates the study area but rather to highlight the sensitivity (if this is so) of the Wattled Crane to land use practices and ultimately to find workable solutions that can benefit both the landowner and the Wattled Crane alike. The KwaZulu-Natal region is the stronghold for the South African Wattled Crane population and therefore the conservation of the remaining areas in which Wattled Cranes are found is of paramount importance.

1.5 CONCEPTUAL FRAMEWORK

This applied quantitative research will be pursuing a traditional positivist approach. Investigating the relation between land uses and breeding productivity will entail a thorough understanding of land cover systems and how the changes in land use impact upon breeding productivity. It will be essential to investigate how management practices can, if at all, be implemented to boost productivity, without impinging on other species. A sound understanding of agricultural systems is needed to understand the rationale behind land use changes and the economic and ecological implications thereof. Figure 1.1 illustrates the various aspects that will be investigated during this research.

It is envisaged that this study will contribute not only to the conservation of the Wattled Crane within South Africa but also to the education of the private landowners about the importance of conservation on their land and about their responsibility to ensure that the species that occur on their property are adequately conserved for the enjoyment by future generations.

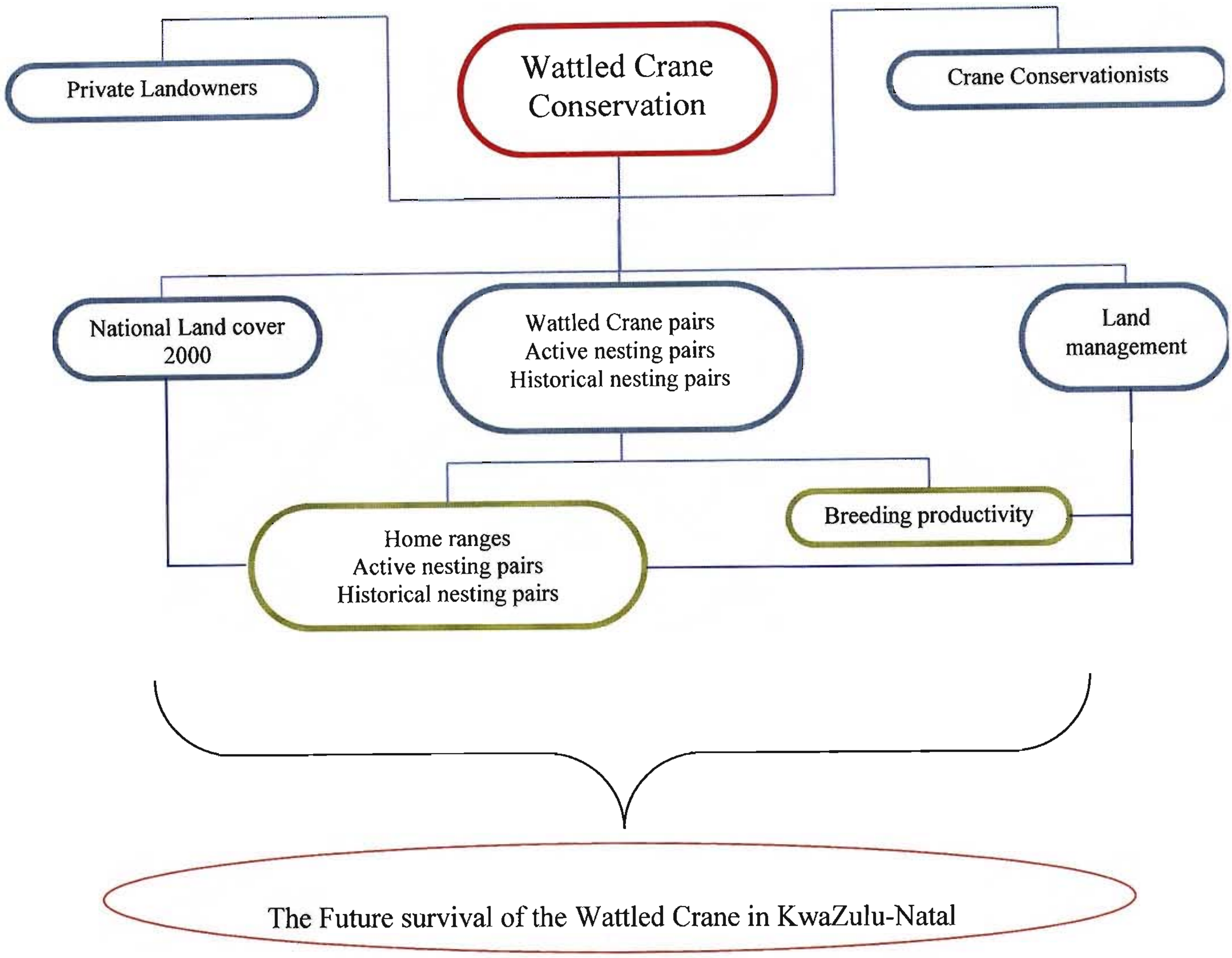

Figure 1.1: Conceptual framework of this study.

1.6 STRUCTURE OF THIS THESIS

The structure of this thesis departs from the conventional style in that it is divided into two components. The first component, component A, follows from this introduction and the chapters include a thorough review of the available literature pertaining to Wattled Cranes, agriculture and Geographic Information Systems and the proposed methods to be utilised within this study. Component B, follows the style of an academic paper, that is to be submitted to a peer reviewed journal for publication. The style of the paper in Component B adhered to the chosen journal's guidelines: the Journal of Agriculture, Ecosystems and Environment.

The literature review allows for a better understanding of the current conservation status of the Wattled Crane, the factors that have an impact on its survival and how the potential usages of a Geographic Information System can be utilised to aid in crane conservation. As the majority of Wattled Cranes occur within the agricultural landscape, it is important to gain an understanding of the factors that currently operate within this landscape and how such factors impact upon the Wattled Crane.

In the section on methods, the proposed methods that will be utilised for this study and how the data will be presented and interpreted are described. This departs from convention in that the methods are described before the actual data collection is to take place i.e. in the future tense and not once the data has been collected and analysed. This study did however conduct a pilot study, which is highlighted in this chapter and as such the data collection to be followed in component B has deviated somewhat as a result thereof.

2. LITERATURE REVIEW

2.1 INTRODUCTION

Cranes are large, graceful, terrestrial birds that occur throughout the world with the greatest diversity of genera occurring in Africa and of species, in Asia. They are easily recognisable with their imposing size and refined proportions (Del Hoyo 1992), preferring the open spaces of the world's grassland and wetland areas. Their distribution is varied, occurring from the North American and Asian tundras to the tropical areas of Asia, Australia, North America and Africa. It is uncertain why cranes never colonised South America (Harris 1994).

The distinctive features that are exhibited within the Crane family, Gruidae, reflect the varied evolutionary history and ecological niches of the different species. Crowned Cranes have a long prehensile toe which enables them to roost in trees and other structures, unlike other members of the crane family who are restricted to roosting on a flat surface. Both the Blue Crane (*Anthropoides paradisea*) and Demoiselle Crane (*Anthropoides virgo*) have short bustard-like toes, an adaption to their grassland habitats, and they have relatively short bills which allow them to forage for seeds, insects and other food items typical of grassland habitats. All other cranes display adaptations to more aquatic conditions i.e. elongated necks and bills, long bare legs and broader feet (Meine & Archibald 1996). The degree to which cranes are dependant upon wetlands varies widely amongst and within the species. Wattled Cranes within central Africa nest within large floodplain wetlands when water levels peak during the annual floods and the birds remain within the wetlands throughout the year. However, in contrast, the Wattled Cranes within South Africa, Zimbabwe and Ethiopia utilise small montane wetlands surrounded by grasslands and they nest during the dry season. Cranes are gregarious by nature, and occurr in large flocks or family groups to both feed and roost, especially during the non-breeding season. They are opportunistic and somewhat nomadic during the non-breeding season and will move from area to area in search of food and security. Such behaviour is universal and provides security to the flock as well as offering juvenile and single birds the opportunity for pair formation (Del Hoyo 1992).

The greatest threat facing cranes is habitat loss and degradation, predominantly as a result of agricultural development and increased human demand for and consumption of the products of both grasslands and wetlands (Meine & Archibald 1996). Agricultural development has had a varying impact on cranes and their habitat. The destruction of wetlands through draining or damming has deprived most cranes of suitable habitat to varying degrees but no more so than to the wetland-dependant Wattled, Siberain (*Grus leucogeranus*), Whooping (*Grus americana*) and Red-crowned (*Grus japonensis*) Cranes (Meine & Archibald 1996). In stark contrast, certain species have benefited from agricultural transformation which has provided more suitable foraging areas in and around breeding areas.

Africa is home to six species of cranes, of which four are resident year round, namely the Blue, Grey Crowned (*Balearica regulorum*), Wattled and the Black Crowned (*Balearica pavonina*) Cranes; resident and wintering populations of the fifth, the Demoiselle Crane and wintering populations of the sixth, the Eurasian Crane (*Grus grus*). The Continent of Africa is fortunate in that it has the greatest diversity of genera of crane species, but unfortunately the four resident species are classified as being threatened under the Red list category of the International Union for the Conservation of Nature (IUCN) and as such, the conservation status of these birds is of growing concern (Meine & Archibald 1996).

2.2 THE WATTLED CRANE

The Wattled Crane (Plate 1) is the largest and rarest of the six crane species that occur within Africa (Johnson & Barnes 1991; Burke 1996). These large birds, endemic to the continent are characterised by their two distinct chin wattles and long beak (Konrad 1981), and inhabit some of the world's largest and diverse wetland ecosystems. It is the most wetland-dependant of all Africa's crane species and as such its low population numbers and 'Critically Endangered' conservation status within South Africa is an indicator of the poor state of the country's wetland habitats (Burke 1996).

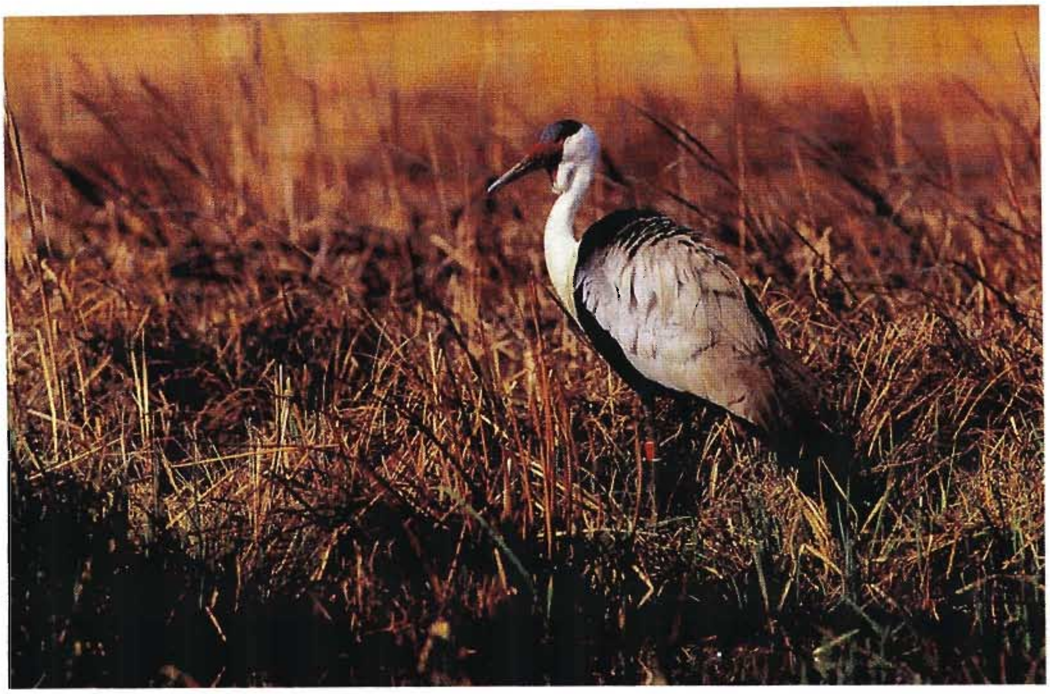

Plate 1: The Wattled Crane (Photo: W. Tarboton).

2.2.1 African Distribution

Three main subpopulations are recognised across the continent with the main subpopulation occurring in south-central Africa (Mozambique, Zambia, Botswana, Angola, Democratic Republic of Congo, Namibia, Tanzania and Zimbabwe). Two smaller subpopulations occur within the highlands of south-western Ethiopia and South Africa (Konrad 1981; Johnsgard 1983; Burke 1996). There is no evidence to suggest that there is movement between the South African population and populations located further north (McCann, Shaw, Anderson & Morrison 2001; Jones, Rodwell, McCann, Verdoorn & Ashley 2001). Figure 2.1 illustrates the location of these three distinct populations.

2.2.2 South African Distribution and Population

The type specimen for the species was collected from The Cape of Good Hope circa 1789, yet the exact location and date are unknown (Brooke & Vernon 1988). The former distribution of the Wattled Crane in South Africa extended to the south-western Cape Province, yet the paucity of the records suggests that the birds were never abundant in this region (Walkinshaw 1965; Vernon & Boshoff 1986). In contrast, breeding has been well documented for KwaZulu-Natal, north-eastern Free State and

Mpumalanga provinces (West 1976; Johnsgard 1983), the areas which presently form the stronghold for this species.

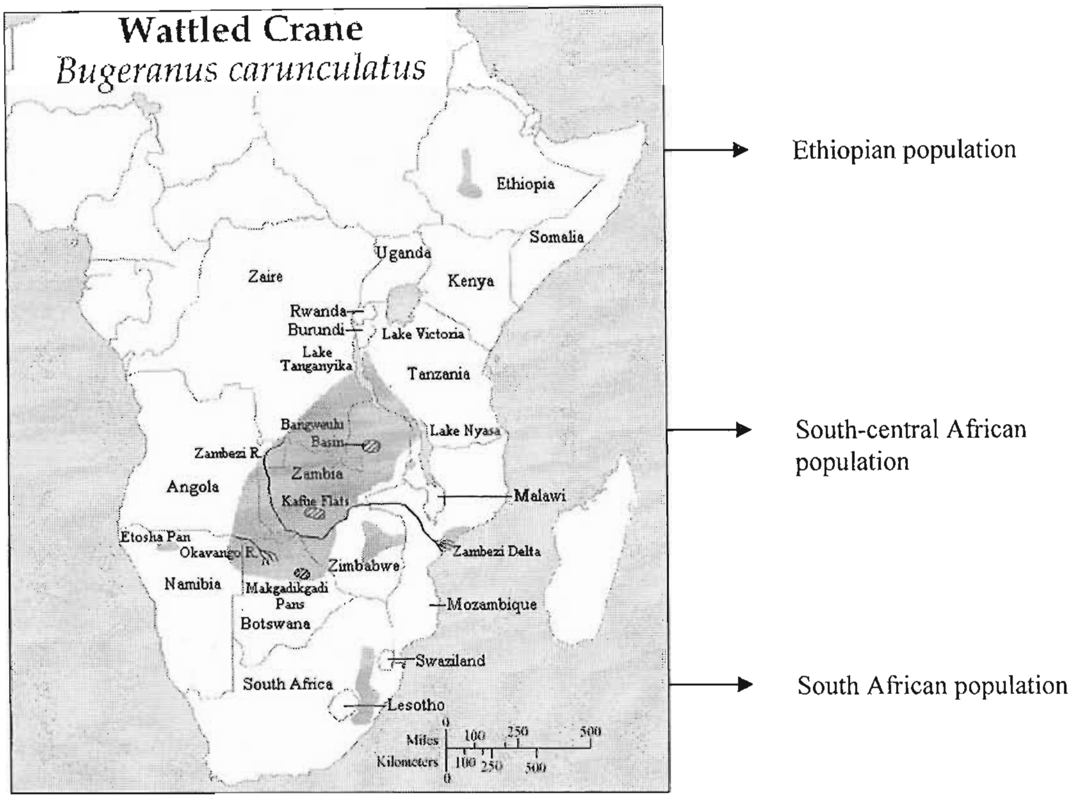

Figure 2.1: Distribution of the Wattled Crane across Africa (Meine & Archibald 1996).

The Wattled Crane presently occupies a very restricted and fragmented range predominantly within the eastern regions of the country. Two subpopulations occur; one in the northern parts of the eastern escarpment (Mpumalanga province) and the other in the south-central parts of KwaZulu-Natal (McCann & Benn *in press*). McCann and Wilkins (1995) state that the population figures for Wattled Cranes have been low (in comparison to historical figures) for a number of years, confirming that their once widespread historical distribution is limited to these two subpopulations. Two small isolated populations occur in the north-eastern Free State, around the town of Memel and in the north-eastern Cape, around the towns of Ugie and Maclear (McCann 2000a). Table 2.1 depicts the population estimates for these subpopulations.

Table 2.1: Population structure of South Africa's Wattled Crane subpopulations

	1982		1994		1999	
	Br ind[a].	Floaters[b]	Br ind.	Floaters	Br ind.	Floaters
Mpumalanga	92	5	16	5	16	5
Free State	2	0	4	0	4	3
Eastern Cape	4	0	9	1	9	1
KwaZulu-Natal	220	56	152	40	130	67
[a]=Breeding pairs [b]=Non-breeding individuals						
Totals	379		224		234	

(McCann 2000a)

The KwaZulu-Natal subpopulation is the larger of the two and is restricted to the higher altitude areas of the midlands and southern Drakensberg. The subpopulation consists of 65 breeding pairs and 67 non-breeding individuals, constituting 84.2 % of the entire South African population (McCann 2001).

2.2.3 Ecology of the Wattled Crane

The ecological aspects of the Wattled Crane are discussed below.

Breeding biology

The Wattled Crane is a monogamous species, whose individuals pair for life and only replace a mate in the event of death (Konrad 1981; Meine & Archibald 1996). It is almost impossible to distinguish the male from female Wattled Crane as they are identical in their external features, however the male can potentially be larger than the female (Meine & Archibald 1996). Wattled Cranes, like other crane species, exhibit intricate activities when forming the pair bond. Such activities are dominated by elaborate and enthusiastic dancing that has become a trademark of cranes. Although dancing serves a variety of functions, its main function is to facilitate socialization and pair formation. New pairs will dance more frequently during courtship compared to well established pairs, who do not have to synchronise their behaviour to the same extent, and thus dance less during this critical period. However, these pair bonds are forged only once a chick has been hatched and until such time, individuals will change partners (Morrison 1998).

The breeding activities of the Wattled Crane have been well documented with Johnson and Barnes (1991) finding the Wattled Crane to have an extended breeding season between April and November with a distinct peak in June in KwaZulu-Natal, yet information has been recorded showing nesting throughout the year (Tarboton, Barnes & Johnson 1987; Urban & Davenport 1993). Wattled Crane pairs in Zambia also tend to breed throughout the year exhibiting peak activity during June (Johnsgard 1983), despite the stark contrast in breeding areas that these two distinct populations utilise. The incubation period for Wattled Cranes is the longest of any crane species, ranging from 33 to 36 days (Burke 1996), 36 to 40 days (Abrey 1992) and up to as many as 40 days (West 1963). The parental responsibilities are shared between both parents with each performing incubation duties. Meine and Archibald (1996) states that the female usually incubates during the evening; this is in contrast to the findings of Walkinshaw (1965), who observed the male (the larger of the two birds) incubating in the evening. Considering the near impossibility of discerning the difference between the two sexes, this may not necessarily have been the case. The sharing of parental duties is however not limited to the incubation period and each parent will contribute to the raising of the offspring. Wattled Cranes have the smallest clutch size of all crane species (Johnsgard 1983) and although occasionally two eggs are laid, only one chick is ever reared (Konrad 1981; Burke 1996). The second egg, being laid 2 to 3 days after the first, acts merely as an 'insurance measure' in the event of the first egg being addled or not hatching successfully (Tarboton *et al.* 1987; Johnson & Barnes 1991). This second egg is abandoned shortly after the hatching of the first as the parents move the young chick off into the wetland to forage. This second egg is either pushed off the nest into the surrounding moat or destroyed by a predator (Abrey 1992).

Both parents assist in teaching foraging and survival techniques to their offspring and although Wattled Crane chicks fledge at between 90 and 130 days of age they will remain with the parents for some time thereafter. This is the longest fledging period of all 15 species and it is during this phase that the majority of first year mortalities occur (Abrey 1992; Burke 1996). Four distinct age classes are described by McCann (2000a) for Wattled Cranes, namely:

- Unfledged chicks that are still with the parents,

- Fledged chicks up to 1 year old that are still with the parents, commonly referred to as juveniles[1],
- Individuals that have moved away from their parents and been introduced into the non-breeding floater flock, yet still have to reach maturity, referred to as immatures, and
- Individuals who are mature enough to breed.

It is difficult to discern the difference between immature individuals and breeding birds except where a pair occurs within a known breeding territory (Meine & Archibald 1996). It is within the non-breeding flock that immature Wattled Cranes will actively seek out a mate. Morrison (1998) describes the formation of dyad relationships between immature individuals from about 14 months of age within such a flock. These dyad relationships occur between males and females, and an immature bird can have several such relationships before finally forming a monogamous bond with a partner. The age of maturity of Wattled Cranes in the wild is unknown, yet they are known to mature sexually in their fourth year of age, an assertion which is supported by laparoscopic examination (Konrad 1981; Abrey 1992). The re-sighting of a colour ringed breeding Wattled Crane in the wild indicates that Wattled Cranes are able to breed successfully from seven years of age (Coverdale & McCann 2003), which concurs with the estimation of Johnson and Barnes (1991) that cranes are unlikely to breed before six years of age. The earliest recorded breeding age for Wattled Cranes in captivity is eight years (Johnsgard 1983). According to Morrison (1998), cranes in general will breed for the first time between three and eight years of age, which thus supports the above findings.

The success of any species is often expressed in terms of its breeding productivity and such is the case with the Wattled Crane. Breeding productivity can be expressed either as the number of young raised per pair per annum (y/pr-yr) i.e. fledgling success or the success rate of clutches laid (young hatched per clutch laid) i.e. hatching success (Tarboton *et al.* 1987). The use of fledgling success as a determinant of breeding productivity has been used for the Common Crane (*Grus grus*) in Sweden whilst hatching success has been utilised for the Lesser Sandhill Crane (*Grus canadensis*

[1] The literature groups unfledged chicks and fledged chicks still with the parents into a single group referred to as juveniles.

canadensis) in Alaska (Boise 1976; Bylin 1987). Both fledgling and hatching success have been utilised to determine breeding productivity of all three crane species within South Africa (Tarboton *et al.* 1987; McCann & Wilkins 1995; Morrison 1998). Within KwaZulu-Natal, the hatching success for Wattled Cranes is estimated to be 55%, whilst 47% of hatched young are estimated to reach the fledging stage yet this figure may be as low as 30%. Of those individuals that reach fledgling age, 75% are estimated to survive till at least one year old (Johnson & Barnes 1992; McCann & Wilkins 1995).

Habitat requirements

The habitat that is utilised by a bird species will vary in quality in differing locations, as far as the benefits that it will confer on its inhabitants in terms of survival and reproduction. As a result thereof, prime habitat is occupied first in preference to poorer or more marginal habitat (Newton 1998). Thus, as prime habitat decreases and a species is forced to utilise more marginal areas, its ability to survive and reproduce successfully is reduced. This is applicable to the majority of cranes which are habitat specific species and therefore the future survival of the species could depend on the availability of suitable habitat.

The Wattled Crane is the most wetland-dependant of all Africa's crane species. A preference is exhibited towards large floodplain wetlands of predominantly sedge-based vegetation for nesting and foraging yet cranes will utilise smaller wetlands throughout their range (Burke 1996). Within South Africa, Wattled Cranes utilise high altitude, palustrine wetlands, bounded by moist or dry, flat or undulating grasslands for both feeding and breeding requirements (Plate 2) (Walkinshaw 1965; Vernon, Boshoff & Stretton 1992; McCann & Wilkins 1995; Morrison & Bothma 1998). This is in contrast to the large floodplains utilised by the majority of Wattled Cranes (more than 95%) within the rest of the species range (Konrad 1981; Beilfuss & Allan 1996).

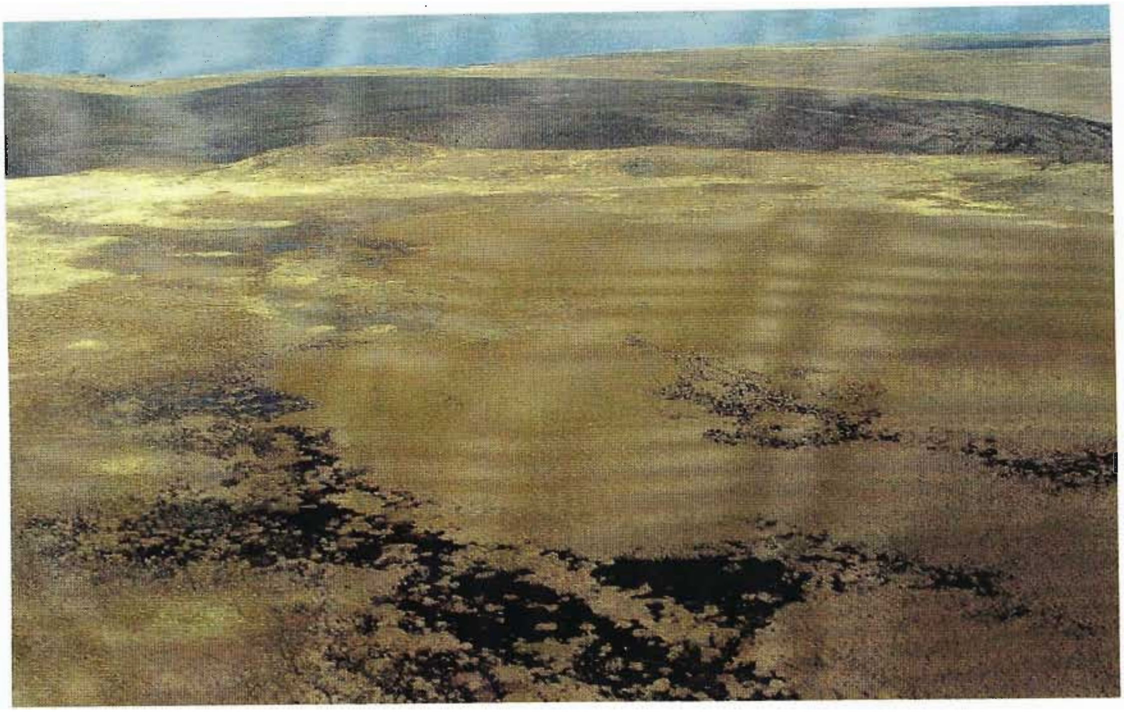

Plate 2: Typical Wattled Crane Habitat – A High altitude palustrine wetland.

Adult breeding pairs are highly territorial and will defend territories of >1km^2. They will maintain territories throughout the year, yet may vacate these areas for short periods when introducing offspring to the non-breeding flock. In contrast, non-breeding individuals will move between traditional foraging areas (Konrad 1981; Johnsgard 1983; McCann *et al.* 2001). Subjective assessments, through the observation of pairs, have calculated the home range of Wattled Cranes to be between 1.3km^2 and 1.8km^2 (mean=1.5km^2) centred around the nesting wetland (Tarboton 1984), yet McCann and Benn (*in press*) have calculated the home range of Wattled Cranes within KwaZulu-Natal to be 16.26km^2 (sd = 24.29km^2) utilising the Kernel Utilization Distribution technique. This technique leads to a more precise probabilistic definition of a home range and it allows for the probability of finding an animal at a particular location on a plane to be determined. The home range is calculated by drawing equal height contours around the utilisation distribution, with the overall home range being such that 95% of the animal's locations are within the contour. The home ranges for Wattled Cranes consist predominantly of open natural grassland, yet agricultural land also contributed significantly to the final composition. Despite this relatively large home range in comparison to other crane species (Florida Sandhill Crane (*Grus canadensis pratensis*) = 2.44km^2; Demoiselle Crane (*Anthropoides virgo*) = 1.44km^2 and the similarly sized

White-naped Crane (*Grus vipio*) = 9.65km^2) (Liying 1993; McCann & Benn *in press*), only 2.3% constitutes the core breeding area. This core-breeding area is that area which is essential for successful reproduction, determined by either hatching or fledgling success. The home ranges of Wattled Crane pairs are smaller when the ranges are dominated by natural vegetation in comparison to those home ranges with a myriad of transformed cover types such as agriculture and commercial forestry (McCann & Benn *in press*). This supports the notion of Newton (1998) that the size of a home range may be influenced by food availability, where the range is larger when food availability is limited than when it is abundant.

The wetlands that are utilised by Wattled Cranes for breeding comprise almost 50% of the core breeding area and vary between 2ha and 293ha in Mpumalanga (Tarboton 1984), whereas within KwaZulu-Natal, the area varies from 10ha to 300ha (Johnson & Barnes 1992). Throughout the areas of Wattled Cranes distribution, nests are a constructed mound of vegetation surrounded by a moat of varying length (Tarboton 1984; Johnson & Barnes 1992). The moat is an essential feature of the nest site, which is created by the trampling of the vegetation by the cranes and the vegetation is then utilised in the construction of the nest (Walkinshaw 1965; Johnsgard 1983). The moat also allows for visibility of potential predators and serves as protection from fire (Urban & Davenport 1993; Morrison & Bothma 1998). Wattled Cranes are known to utilise man-made dams for nesting yet it has been reported that the original wetland was originally utilised for nesting and that the various pairs have been forced to utilise the modified habitat (McCann & Wilkins 1995).

Habitat utilisation

Filmer and Holtshausen (1992) in their findings of the Southern African Crane census identified two distinct habitat types utilised by Wattled Cranes, namely:

- Natural habitat, which constitutes wetlands, grasslands, rivers and unspecified grassland types, and
- Man-modified habitats, comprising pastures, agricultural crop fields and dams.

The census showed that the majority of sightings occurred at the edge of farm dams, followed by wetlands, then grasslands and a very small proportion within agricultural lands. Figure 2.2 illustrates the various habitat types utilised by Wattled Cranes.

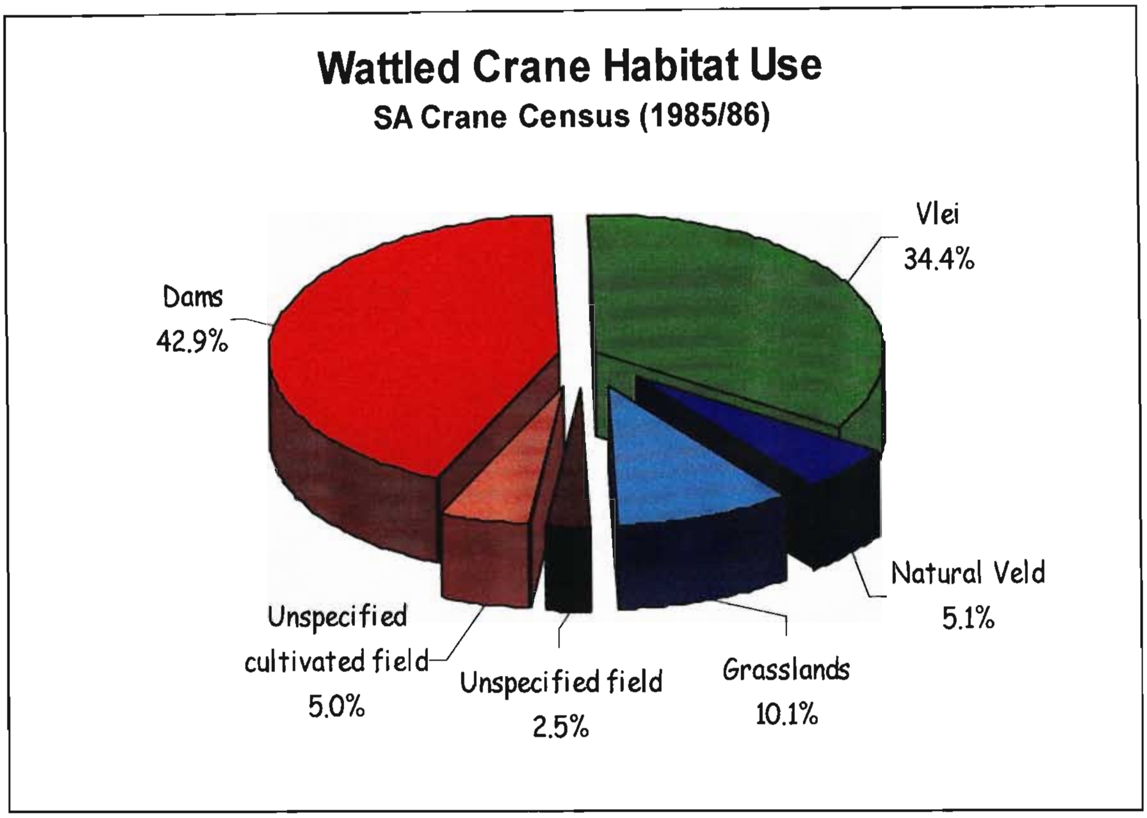

Figure 2.2: The habitat use as shown by Wattled Crane sightings from the South African Crane Census in 1985 / 86 (Filmer & Holtshausen 1992).

McCann (2000a) analysed the sightings data collected through a six-year period of aerial census within Kwazulu-Natal and the results of the various habitat types utilised by Wattled Cranes have been summarised in Table 2.2. McCann's results concur with those of Filmer and Holtshausen (1992) in that both results show that there is an affinity to wetlands, which attests to the dependence of the species on wetlands. Of interest is the reporting of utilisation of dams within both sets of data. The damming of wetlands is regarded as being detrimental to the Wattled Crane. Both sets of data attest to the lack of utilisation of transformed habitats (excluding dams).

Table 2.2: Habitats utilised by Wattled Cranes in KwaZulu-Natal during 1994-1999 (McCann 2000a)

	Breeding Pairs	Non-breeding Pairs	Floater Flock
Vlei	67,3	46,3	28,6
Burnt vlei	8,3	6.0	9,5
Grasslands	6.0	19,4	14,3
Burnt grasslands	3.0	3.0	9,5
Dam shallows	13,7	3,7	9,5
Harvested maize	0,6	9.0	14,3
Ploughed lands	0,0	3.0	0,0
Rye grass pasture	1,2	5,2	9,5
Eragrostis pasture	0,0	2,2	4,8
Kikuyu pasture	0,0	0,8	0,0
Fallow field	0,0	1,5	0,0

The occurrence of transformed land cover types within the Wattled Cranes' home range suggests that the species will tolerate a certain degree of disturbance within its home range. Harvested croplands are utilised as foraging areas during the non-breeding season and are a major source of food during the early winter period prior to breeding (McCann & Benn *in press*). However, habitat selection is area-specific and thus information cannot be extrapolated throughout the range of the species and therefore each subpopulation needs to be analysed individually (Morrison 1998).

Feeding requirements

The diet of the Wattled Crane consists primarily of sedge-based vegetation which includes the tubers and rhizomes of *Cyperus* and *Eleocharis* spp. Foraging is aided by the bird's long beak which is utilised to probe the moist sub-surface wetland area enabling the bird to utilise the myriad of aquatic plants that grow in the shallow water of its wetland habitats (Douthwaite 1974; Johnsgard 1983; Tarboton 1984). The grasslands that surround the majority of wetland areas are utilised for foraging for grass seeds, grain and insects. In areas that have undergone agricultural transformation the agricultural lands are also utilised whenever convenient (West 1963; McCann & Wilkins 1995; Burke 1996).

2.2.4 Threats

There are numerous threats facing the Wattled Crane, some unique to each range state whilst others are common to the Wattled Crane's entire distribution. The species move substantially within their distribution and are thus exposed to a wide variety of threats (McCann 2000b). Five principle threats are discussed below.

Habitat loss

The loss of habitat, both breeding and feeding habitat, constitutes the greatest threat to Wattled Cranes. The loss of wetlands through damming, modification through draining for agricultural purposes or the degradation of habitat constitutes the single greatest contributing factor to the decline of Wattled Cranes within South Africa (Plate 3) (Vernon & Boshoff 1986; Johnson 1992; McCann & Wilkins 1995; McCann 2000a).

It is estimated that over 50% of KwaZulu-Natal's wetland resource base has been lost or altered over the past 100 years (Begg 1990), a situation not uncommon to the rest of South Africa and across the globe (Pienkowski, Bignal, Galbraith, McCracken, Stillman, Boobyer & Curtis 1996; McCann 2002). The present breeding range of the Wattled Crane falls entirely within the grassland biome, as defined by Low and Rebello (1996), and it is this grassland that surrounds the breeding wetland that is as important for successful breeding as the wetland area itself. These grassland areas have undergone extensive transformation and are at high risk of being transformed by exotic timber plantations, a land use type totally incompatible with Wattled Cranes, and by agricultural intensification for increased food production (West 1976; Adie & Goodman 2000; McCann 2000a). Plate 3 illustrates the loss of suitable Wattled Crane habitat to both agricultural development, through the ploughing of grasslands and the damming of wetlands, as well as the loss of grassland to afforestation. It is this same grassland biome that has been identified as being critically endangered and the biome most in need of conservation attention (Neke & du Plessis 2004). However, despite the multiplicity of sources and the severity of the threat, the grassland biome has been afforded little protection and remains under threat. Adie and Goodman (2000) conclude that all grasslands within KwaZulu-Natal should be considered as being severely threatened. Ronchini (1998) concludes that the areas of natural vegetation surrounding breeding sites are critical to the successful breeding of Wattled Crane pairs.

Hydroelectric power schemes and other large-scale water development schemes have resulted in fundamental changes in the Wattled Crane's expansive floodplain habitats across Africa. Large impoundments disrupt the natural flood patterns by the reduction of the stream flow during the wet season and by the increase in it during the dry season. This disruption not only diminishes the range of the floodplain habitat but also alters the vegetation communities as well as facilitating the burning of grasslands which in turn reduces the availability of suitable breeding and feeding areas (Burke 1996).

Plate 3: The destruction of Wattled Crane habitat, through afforestation and agricultural development.

The direct loss of habitat within the landscape and the subsequent composition of available habitat is not the only factor influencing the distribution and population numbers of the Wattled Crane. The fragmentation of wetlands and grasslands, as a result of human activities, has resulted in the decline of numerous bird species, the Wattled Crane included (Newton 1998, Ratcliffe & Crowe 2001) and as such the configuration of available habitat within the landscape plays a crucial role in the distribution of the Wattled Crane. Non-migratory species, such as the Wattled Crane suffer greater population declines through such habitat fragmentation, in comparison to migratory species. It is thus imperative that linkages and corridors, or so-called 'stepping stones' (McGarigal & Marks 1994) are maintained between suitable breeding and foraging areas.

Habitat management

The mismanagement of areas within which the Wattled Crane breeds and feeds has also had a detrimental effect on the bird's numbers (Abrey 1992). Wetland areas are frequently burnt to act as fire breaks during the winter months which coincide with the peak breeding season of the Wattled Crane (McCann 2002) thus resulting in the possible loss of both eggs and unfledged chicks (Plate 4).

Plate 4: Indiscriminate burning of wetlands during the Wattled Crane breeding season.

*: Eggs located on the nest protected by the moat

Wetland areas are frequently utilised as grazing areas for domestic livestock, resulting in breeding birds having to vacate nests for extended periods, often resulting in the eggs becoming addled. The grazing of wetland areas can however help to open up certain areas within the wetland and thereby to expose vegetation that may have been previously inaccessible to the birds. The mismanagement of habitat through indiscriminate burning practices, resulting in the decline of species has been well documented for a number of bird species across the globe (Gilpin, Gall & Woodruff 1992; Díaz, González, Muñoz-Pulido & Naveso 1996; Pienkowski *et al.* 1996) and is thus not unique to the Wattled Crane.

Disturbance

Disturbance at or near breeding sites as a result of human activity constitutes another major threat to the survival of the Wattled Crane. It can result in pairs not being able to form the much needed pair bonds prior to commencing breeding. It can result in nest abandonment once breeding has commenced or in lengthy time periods off the nest resulting in the eggs becoming addled (Burke 1996). Disturbance combined with inappropriate habitat management, is a significant limiting factor to the successful breeding of Wattled Cranes.

Poisoning and agrochemicals

As the transformation of natural grassland areas increases, Wattled Cranes are forced to increasingly utilise agricultural areas for foraging and so are vulnerable to accidental or purposeful poisoning (Burke 1996). Certain pesticides are particularly persistent in the environment and have been responsible for the decreased breeding productivity of a number of bird species (Orians & Lack 1992), most notably the Peregrine Falcon (*Falco peregrinus*). The reduced availability of insects, through the increased usage of herbicides has led to the decline of Grey Partridges (*Perdix perdix*) in North America for instance (Southwood & Cross 1969). The decline in food sources e.g. insects as a result of increased pesticide usage can also impact negatively on a bird species, as it results in individuals having to expend more energy in order to meet their daily food requirements (Benton, Bryant, Cole & Crick 2002). The extent to which agrochemicals may be limiting food availability for Wattled Cranes is uncertain and has not been discussed in the literature, but the impact as a result of poisoning is well documented.

Other threats

Burke (1996) identifies various other anthropogenic factors that have contributed, and continue to contribute, to the decline of the Wattled Crane. These include:

- Collision with overhead utility lines – This is unique to South Africa, partly as a result of increased habitat transformation and human expansion and is not limited to cranes but includes a number of large terrestrial birds,
- Illegal collection of eggs, chicks and adults for food,
- Tsetse fly control – Mass aerial spraying associated with the control of tsetse fly, especially within the Okavango Delta, is suspected to have had a negative effect on the Wattled Crane.

Natural threats include hail, extended drought periods, fires and the desiccation of floodplains.

2.2.5 Conservation Projects

The decline in numbers of the Wattled Crane across its entire distribution area has resulted in widespread conservation efforts by numerous government departments and non-governmental organisations. The large territories that Wattled Cranes require and their being conspicuous inhabitants of wetland and accompanying grassland areas has ensured that conservation activities undertaken on their behalf have benefited numerous other species (Del Hoyo 1992).

The South African Crane Working Group (SACWG), a working group of the Endangered Wildlife Trust (EWT), was formed in 1995 to lead crane conservation efforts across South Africa. In conjunction with other dedicated Non-Governmental Organisations (NGO's), such as the KwaZulu-Natal Crane Foundation (KZNCF) and the Overberg Crane Group (OCG), the SACWG has been largely responsible for crane conservation efforts in South Africa. The failing capacity of formal conservation organisations has increased the importance of such NGO conservation efforts and the following are projects and activities presently undertaken by both SACWG and the KZNCF (SACWG 2004):

- Education and Awareness: 90% of all cranes occur on privately owned land and as such the core activities to date of both the KZNCF and SACWG have been focused on education and awareness. Target groups of the respective organisations have included landowners, their staff, rural communities and both rural and urban schools.

- Crane Population Management programme: The focus of this programme is to reduce the current levels of mortality of the various crane populations, by means of the following strategies:
  - Working closely with agrochemical management on farms to reduce the number of poisoning incidents.
  - Participating in the Eskom / EWT Power line Interaction project and working closely with Eskom to identify hazardous power lines and mitigate these problems, to reduce the number of power line collisions and electrocutions.
  - Working closely with the landowners and staff in specific farm management activities which may disturb / affect the cranes.
- Specific research, monitoring and information collection programme: SACWG has established a central database in order to secure all crane data i.e. sightings, mortalities, banding records, etc. A need for detailed, relevant research has been identified to better understand crane conservation management and the SACWG has initiated the following projects:
  - Annual aerial counts
  - Monitoring breeding productivity
  - Crane home range and habitat analyses
  - Crane movement studies, using both satellite telemetry and colour ringing
  - Genetics analysis of South Africa's crane populations
  - A study on the habitat requirements of Wattled Cranes in South Africa
- Habitat protection and conservation programme: Crane habitat has been severely affected over the last two decades and so the KZNCF and SACWG work closely with the following programmes / organisations:
  - National and Regional Departments of Environmental Affairs and Tourism
  - Regional Departments of Agriculture
  - The Department of Water Affairs and Forestry
  - Various NGO's such as the Mondi Wetland Project, Wildlife and Environment Society of Southern Africa (WESSA), Birdlife South Africa, National Conservancies Association and other working groups of the EWT.
- The SACWG / African Association of Zoos and Aquaria (PAZZAB) Wattled Crane Recovery Programme: The focus of this programme is on boosting the wild

Wattled Crane population with chicks hatched from eggs collected as second, abandoned eggs, from nests in the wild. To ensure the proper rearing of chicks that are suitable for release, a technique known as 'isolation-rearing' is used. This allows for a large number of chicks to be reared at one time, ensuring proper imprinting and through human avoidance conditioning, produces chicks fearful of humans.

2.3 AGRICULTURE AND CONSERVATION

2.3.1 Introduction

Agriculture is the prevailing interface between mankind and nature and has become a dominant form of land management around the world, increasing in intensity after World War II (Gall & Orians 1992; Gilpin, Gall & Woodruff 1992). This intensification has contributed positively to increased production yields through technological advances in machinery, fertilizer and pesticides yet it has simultaneously had a negative impact on biological diversity (Briggs & Courtney 1989; Piper 1999). Over the last 40 to 50 years the agricultural industry's methods and systems have changed from being relatively favourable to wildlife and biodiversity to being a highly specialised and technical business, whose main function contradicts the maintenance of diversity sought by conservation (O'Connor & Shrubb 1986). Agricultural landscapes have become dominated by monoculture enterprises, which require a form of land use which results in highly productive feed and food production units, and which simultaneously negative impacts on the biodiversity within these same landscapes (Piper 1999). Agriculture has reduced highly diverse natural ecosystems into simplified production units, and has contributed to the pollution of soils and waterways and hastened the spread of alien biota (McNeely & Scherr 2003).

2.3.2 Positive Effects of Agriculture on Biodiversity

Agriculture can have a positive effect on the wildlife that inhabits the same areas. The resultant mosaic of habitat as a result of fragmentation results in the creation of the 'edge effect', which in turn creates new niches that allow for the expansion of certain plant and animal communities and which also increases the alpha diversity within a specific area. Species that exhibit small area requirements or that are highly mobile and can easily migrate between small habitat patches, thrive in such altered or fragmented habitats (Lacher, Slack, Coburn & Goldstein 1999). The agricultural landscapes that results can also provide alternative food sources. Grain agriculture provides residue seed after harvesting which serves as a vital resource to many wildlife species and all three species of cranes in South Africa are known to utilise harvested maize (*Zea mays*) areas for foraging.

The transformation of natural habitat does not always have a detrimental effect on the species living in it. The transformation of natural habitat in the Western Cape, in South Africa from a fynbos dominated system to an agriculturally dominated system has boosted Blue Crane numbers, to the point that the region is now home to more than half of the world's entire population (McCann *pers comm.* 2004). This is in stark contrast to the well documented decline of both the Blue Crane and Wattled Crane in the eastern parts of South Africa as a result of habitat transformation (Vernon & Boshoff 1986; Johnson 1992; McCann & Wilkins 1995; McCann 2000a).

Biodiversity in itself also contributes to the productivity and sustainability of agriculture and forestry. A variety of species, through a number of differing actions influence the composition and structure of natural vegetation, the reproductive success of plants, soil fertility and the regulation of pests. Biodiversity is responsible for pollinating plants (birds, bees, bats etc), decomposing waste (earthworms, dung beetles, vultures and micro-organisms), dispersing seeds (birds, primates, ants, etc) and maintaining species equilibrium through predator –prey interactions (McNeely & Scherr 2003).

2.3.3 Negative Effects of Agriculture on Biodiversity

The loss of natural habitat has been the major result of agricultural transformation (Gilpin *et al.* 1992). Such transformation directly reduces biodiversity, a phenomenon that has been recorded the world over (Lacher *et al.* 1999) and transformation in turn leads to the fragmentation of natural habitats. The reduction of available remaining habitat and the resultant increase in the degree of interpatch distances have all contributed to the negative agricultural impacts. The use of more advanced agricultural machinery has meant the eradication of marginal agricultural areas through the consolidation of areas into larger, more productive blocks (Boutin, Freemark & Kirk 1999; Heitala-Koivu 2002). Fragmentation is also considered to be a major factor leading to local extinction as the loss of habitat and the distances between available habitats all contribute to the rate of local extinction. The creation of fragmented natural habitat patches through agricultural systems has been known to negatively influence the survival and breeding productivity of bird populations (Malan & Benn 1999). The 'edge effect', although beneficial to certain species has also proven to have had a negative impact on others. Edges can serve as ecological traps for breeding birds by concentrating nests within small areas with the resultant risk of increases in predation (Lacher *et al.* 1999). However, land use change invariably occurs so rapidly that the resultant impact on wildlife and the ecosystem is only fully realised after the event (Gilpin *et al.* 1992; Lavers & Haines-Young 1996). Therefore, land use practices and their spatial alignment can be used firstly to indicate habitat degradation and secondly to potentially explain the decline of species' populations.

The fragmentation of habitat and associated negative agricultural impacts on biodiversity have resulted in the focus nature conservation efforts and accompanying legislation being primarily on protected areas (Pienkowski *et al.* 1996, McNeely & Scherr 2003). The conservation of biodiversity outside protected areas is imperative for a number of reasons, which include (Pienkowski & Bignal 1993, *cited in* Pienkowski *et al.* 1996):

- Certain species, including birds and mammals require extensive areas, which often include a mosaic of biotopes and becuase of large human populations preclude the establishment of extensive reserves,
- Present protected areas, originally created to protect certain species, are unlikely to maintain viable populations of many species (Gall & Orians 1992; McNeely & Scherr 2003),
- Protected areas are not impervious to their surroundings,
- In response to climatic change, geographical continuity of habitats will be required in order for certain species to shift their ranges, thus ensuring survival, and
- In order to maintain and restore the regional diversity of wildlife and its habitats, it is imperative that nature conservation measures are incorporated into the agricultural landscape.

The integration of conservation requirements into other land use policies, such as those for agriculture, is an integral feature of the Convention of Biological Diversity, a convention that South Africa has ratified. Article 8 (c) of the Convention states that each contracting party shall, as far as possible and as is appropriate: "regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to assuring their conservation and sustainable use" (Halladay & Gilmour 1995 : 105).

Intensification of agriculture makes it possible to provide increased yields, and cereal crops have yielded a global increase of 20% since 1980; such intensification has had a major impact on the environment. The increased production through the injection of energy, fertilizers, pesticides, irrigation systems and the reduction in genetic diversity has ultimately come at a cost of reduced soil fertility, loss of genetic resources, disruption of hydrological systems and increased soil erosion. The costs of these are ultimately passed onto future generations (Briggs & Courtney 1989; McNeely 1995). Despite the potential for conflict between the farmer and conservationist, each party realises the importance of the other. The farmer is conscious of his responsibility as custodian of the land, whereas the conservationist acknowledges the contribution of the farmer to feeding the nation (Lockhart & Wiseman 1988).

2.3.4 Agricultural Systems

Agriculture has been a contributing factor towards the success of the human species and has enabled the human population to expand far beyond what would have been possible through simple hunting and gathering (McNeely & Scherr 2003). Agricultural systems have become highly diverse and can essentially be divided into three types, graded by the intensity and expense of the human inputs. Firstly, there are the systems that require fundamentally no human inputs such as fisheries, grazing systems that are dominated by domestic animals as well as forests that are not subject to clear cutting and replanting. These systems can yield their product indefinitely if exploited correctly. Secondly, there are the systems which require a low input and when managed properly are sustainable, for example conventional forestry. Thirdly, there are systems with a high input and which are dependant on human management and the costly input of energy and chemicals (Gilpin *et al.* 1992). Land users will adjust their production practices i.e. tillage, sowing, fertilizing in order to optimally combine inputs based on natural capital (soil, solar energy, rainfall etc.) and inputs from man-made capital (fertilizers, seeds, pesticides, etc.) to yield the desired outputs/products, all of which will have an impact upon the environment (van der Werf & Petit 2002). The human management of all three systems can fail and subsequent ecological degradation can result. As the degree of management increases, so the biodiversity decreases. Figure 2.3 depicts the connection between the diversity and the management required within any given agricultural system.

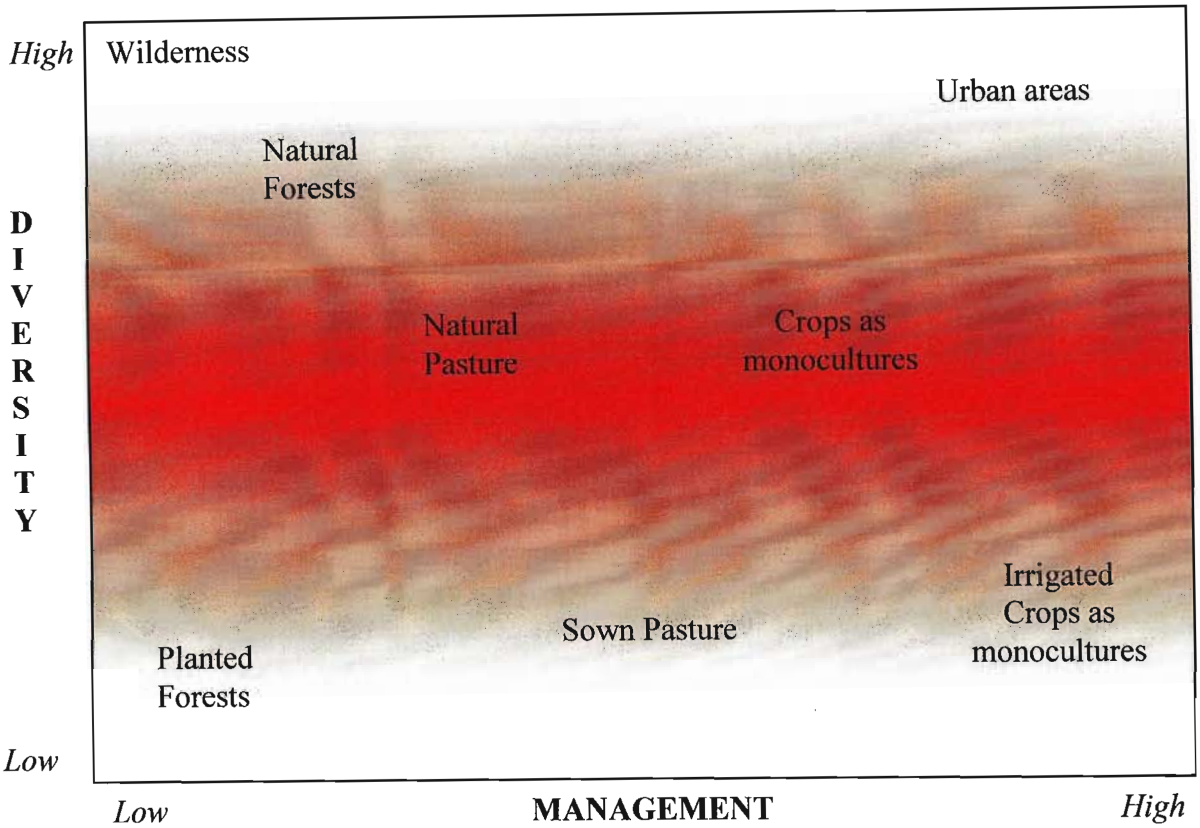

Figure 2.3: The relation between diversity and management within an agro-ecosystem (from Tivy 1990).

Agricultural systems are far more complex than natural systems in terms of their management practices as the manager can control and manipulate the system in a number of ways, from varying fertilization and irrigation techniques through to the timing of activities (planting and harvesting) (Gilpin *et al.* 1992). Environmental factors do however influence these management practices and the choice of tillage, drainage, irrigation and the application of fertilizers and pesticide are dictated by specific environmental conditions or problems (Briggs & Courtney 1989). These various practices must be cost effective so as to ensure that the benefits from increased inputs are realised through either increased output or crop quality. It is true to say that the multiple use of the land declines as the cultivation intensity, and subsequent market value of the crop, increases (Gall & Orions 1992). The agricultural system should consider not only the bio-physical environmental component but also the interaction of the social and political environment as well, yet it is the ecological dimension that is fundamental to the overall sustainability and is a prerequisite for the viability of the economic and social dimensions (Hietala-Koivu 2002). The impact of such systems on the environment can be based either on the land user's practices and factors effecting those practices, a so-called 'means-based' impact or on the effects that such practices have, the so-called 'effect-based' impact. Figure 2.4 illustrates the various components that contribute to the agro-ecosystem system (Tivy 1990; van Duivenbooden 1995; van der Werf & Petit 2002) in which the land user is central, without whom the system would not exist and illustrates how the various components can affect the environment.

Van Duivenbooden (1995) describes the performance of an agricultural system as being dependant on six characteristics, all of which are influenced by the explicit goal of the land user, as follows:

- Productivity – The yield or net income per unit of resource. Productivity is a function of energy flows and material cycles
- Stability – The degree to which productivity is stable when exposed to small disturbances as a result of normal fluctuations of climate and other environmental variables
- Equitability – How fairly the products of an agricultural system are distributed among its human beneficiaries
- Sustainability – The successful management of agricultural resources in order to satisfy the changing needs of humans
- Agrodiversity – The variation in both the biotic and abiotic environments, genetic resources and farmers' management practices
- Landscape quality – The aesthetic contribution to landscape appreciation whose value increases closer to urban areas yet which is constantly changing.

Although agricultural systems have a major impact on the biodiversity of the landscape, certain measures can be implemented to negate the ecological losses caused by these systems. These include, but are not limited to, crop diversification (heterogeneous crop choice and crop structuring), adjacent landscape preservation, the development of biocorridors and bio-centres, crop rotation and modifications to pesticide use (Starý & Pike 1999). However, the continuous increase in man-made inputs into most agro-ecosystems to increase yields may be necessitated by the reductions in the quality of the natural capital i.e. land degradation and thus that of the underlying productive capacity (van der Werf & Petit 2002).

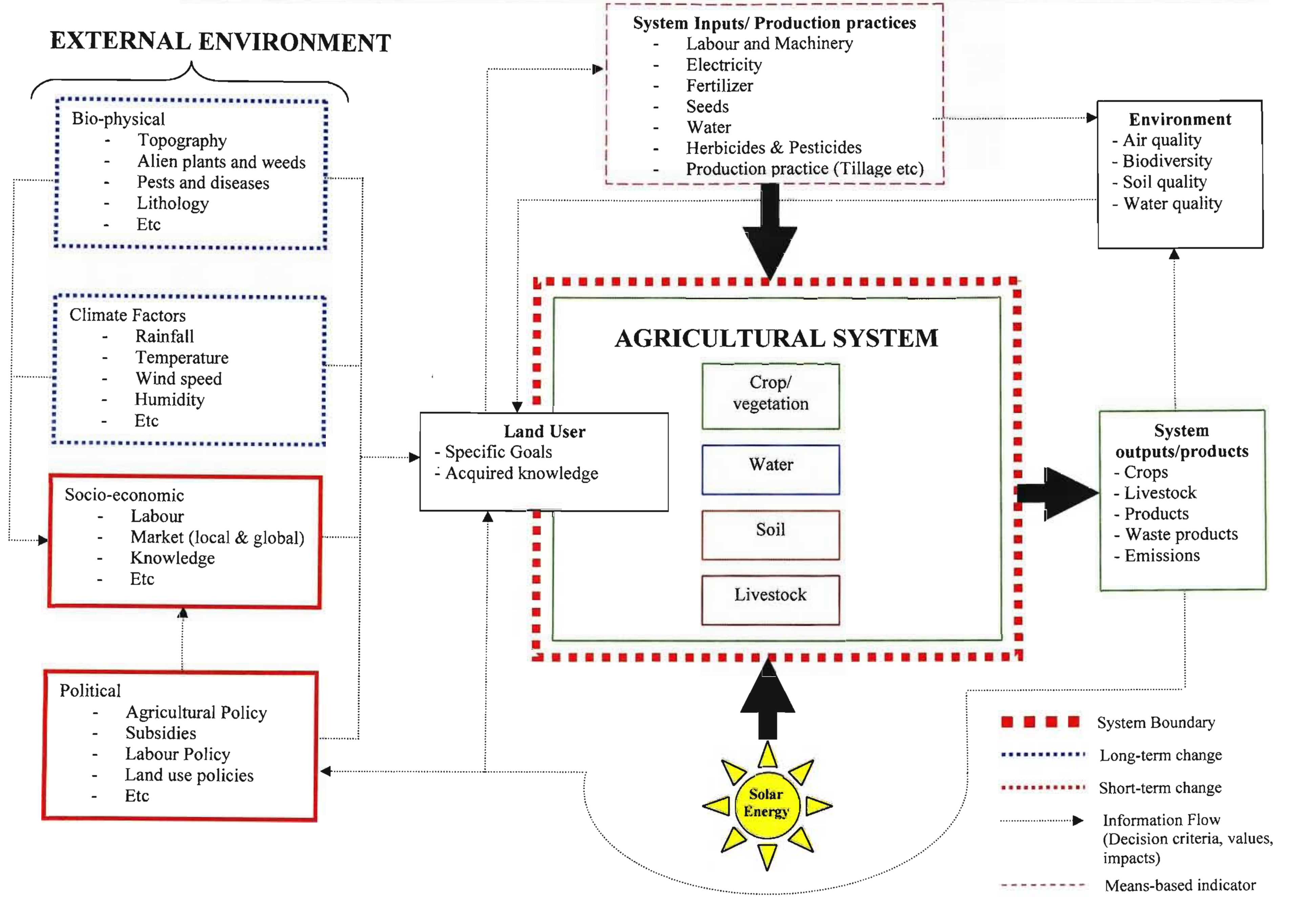

Figure 2.4: Illustration of an Agricultural System (from Tivy 1990; van Duivenbooden 1995; van der Werf & Petit 2002).

2.3.5 The Impact of Agriculture on Birds

The implications for avian fauna as a result of agricultural development are twofold. The first is that particular habitats are totally engulfed and destroyed. Whilst the second is that the surviving habitats become modified through various agricultural practices and consequently the niches that they offer are altered, either making them less or more attractive (as is sometimes the case) to various bird populations (O'Connor & Shrubb 1986).

Within the agricultural landscape, three major factors influence the abundance and distribution patterns of avian species. These factors are:, the types of crops that are grown; the configuration and physical structure of non-crop habitat; and the agricultural practices such as tillage, pesticide application and harvesting (Boutin *et al.* 1999). These three factors and the resultant implications for avian species are illustrated in Table 2.3

Table 2.3: Summary of the main changes in agricultural management and their implications for avian fauna

Change	Effect
Grassland – arable balance	Loss of breeding sites for ground nesters Less area available for feeding Loss of marginal non-crop habitat i.e. wetlands
Choice of crops	Grain crops have replaced permanent pasture and grassland Fast growing forage crop hybrids allow for earlier mowing and cause increased mortalities of ground nesting birds
Combine harvesting	Later, more rapid harvesting which limits food availability and opportunities to forage Less waste grain
Chemical use	Fewer weed seeds and fewer insects Reduced breeding success
Loss of rotations	Reduced diversity of feeding opportunities

(From: O'Connor & Shrubb 1986)

The detrimental effect of disturbance from agricultural activity is often subtle and not as easy to quantify as direct habitat loss. Although the fragmentation of habitat may provide certain bird species with the required nutritive and nesting requirements, the disturbances associated with agricultural intensification through increased pesticide application, harvesting, grazing and burning may reduce the suitability of available habitat (Warner 1994; Malan & Benn 1999). Animals tend to respond to disturbance in the same manner as they would to predation and tend either to avoid certain areas completely or to utilise such areas for only limited periods. This can result in sub-optimal utilisation of much needed resources (Gill, Sutherland & Watkinson 1996).

The availability of certain food types, on which a species is dependant for its existence may also be a limiting factor for certain bird species. Benton *et al.* (2002), suggest that the availability of arthropods within the agricultural landscape can have an impact on certain avian species. It is suggested that the value of such a food source is determined by the physical costs involved in searching for the food as well as the nutritional benefit gained from ingestion. Thus, when arthropods are rare, parental birds will have to work harder in order to obtain the same amount or even perhaps a reduced amount for their chick than when arthropods are abundant. This increase in costs of foraging can have immediate consequences like chick starvation or reduced clutches or the effect may be delayed i.e. reduced fecundity the following year, reduced overwinter survival of both juvenile and parent.

The impacts of agriculture on birds is however not always negative and Guzmán, García, Amado and del Viejo (1999) conclude that the changes and/or increases in agricultural practices is correlated to the increase in numbers of the wintering population of the Common Crane (*Grus grus*). However, many agricultural crops, although high in energy, do not provide the necessary proteins and minerals in comparison to non-agricultural foods and as a result cranes are forced to search for areas where natural foods are available. The presence of bulbs and invertebrates, which may not be present within the agricultural system, can contribute to the supply of the necessary dietary proteins and minerals.

2.3.6 Plantation Forestry and the Environment

Plantation forestry encompasses the planting, tending and harvesting of exotic timber species in a non-forest habitat. The impacts of afforestation on the receiving environment can be summarised as follows (Kirkman & Pott 2002):

- Effects on hydrology i.e. the reduction in stream flow,
- Changes to the surrounding habitat and biodiversity,
- An in increase in habitat suitable for species adapted to alien tree plantations with the resultant decrease in suitable habitat for non-adapted species,
- Potential changes in the soil nutrient status and the associated micro-organisms and,
- Alterations to the landscape e.g. loss of grasslands covered by plantations.

The midlands of KwaZulu-Natal has undergone extensive transformation as a result of plantation forestry, with large tracts of *Pinus*, *Eucalyptus* and *Acacia* spp plantations located throughout the key Wattled Crane habitat (McCann *pers comm.* 2004).

The distribution of the Wattled Crane within the agriculturally dominated region of KwaZulu-Natal and its susceptibility to disturbance makes it a difficult species to research in terms of its habitat requirements. However, advancements in Geographical Information Systems (GIS) and land cover studies are allowing for more meaningful understandings of species habitat requirements which thus could be applied to the Wattled Crane.

2.4 GEOGRAPHIC INFORMATION SYSTEMS (GIS)

2.4.1 Introduction

A wide array of definitions exist within the literature for Geographical Information Systems (GIS), all are dependant on the particular application being utilised. Yet, a common theme that is shared amongst all definitions is that GIS are defined as integrated data-based management systems that are capable of the collection, storage, manipulation (analysis) and output of information which is spatially referenced (Woodcock, Sham & Shaw 1990; Obermeyer & Pinto 1994). GIS have evolved considerably since their origin in the late 1960's (Goodchild 1993) and today have the capability to potentially aid work in diverse fields ranging from environmental management through to sales and marketing. Consequently, a global market exists for products and services related to GIS (Woodcock *et al.* 1990; Goodchild 1993).

GIS are designed to allow for the analysis of data from a variety of sources as well as to derive new information from existing data sources and therein lies the interest in

GIS and their explained growth in a number of fields associated with natural resources, environmental management and urban studies (Woodcock *et al.* 1990). GIS have arisen from activities in four different fields, as illustrated in figure 2.4, each operating independently but interrelated:

- Cartography, which has automated the manual dependency of map making through the substitution of vector digitization,
- Aside from the mere cartographic component of digital vector data, computer graphics has many applications which includes the design of buildings, machines and facilities,
- Databases which have been created to overcome the problems of computer graphics and computer cartography through the application of general mathematical structure, and
- Remote sensing, which has created vast amounts of digital image data in need of geo-rectification and analysis.

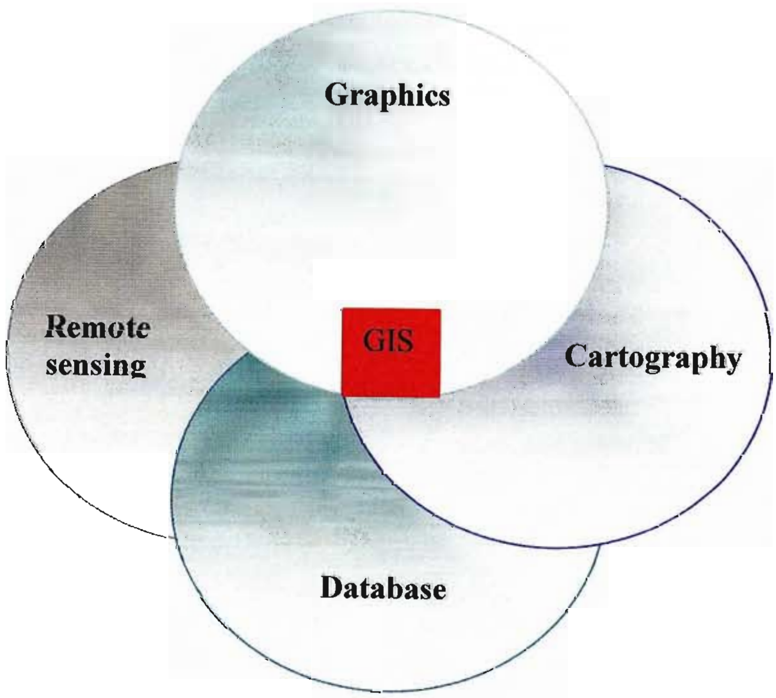

Figure 2.4: Illustration of the interrelationship of the four GIS disciplines (Konecny 2003).

Konecny (2003) represents GIS as being within an interconnected digital model of geography combining data, hardware and software and administration (of which a component is a specific problem or objective). The successful operation of GIS is dependant on the success of each of the three components and the inability to master one will ultimately lead to the failure of the entire system. Figure 2.5 illustrates this concept of GIS, in which the base of all GIS is the data that is inputted, without which the rest of the system would not operate. The type of data varies according to the users' requirements and expected outputs, yet is dependant on the quality of the data that is collected. The old adage of 'garbage in – garbage out', applies to all GIS. The administration of GIS is imperative for successful functioning. Ongoing monitoring is a pre-requisite so as to ensure that the data that is collected is suitable for GIS and that data are not merely collected for the sake of collecting data.

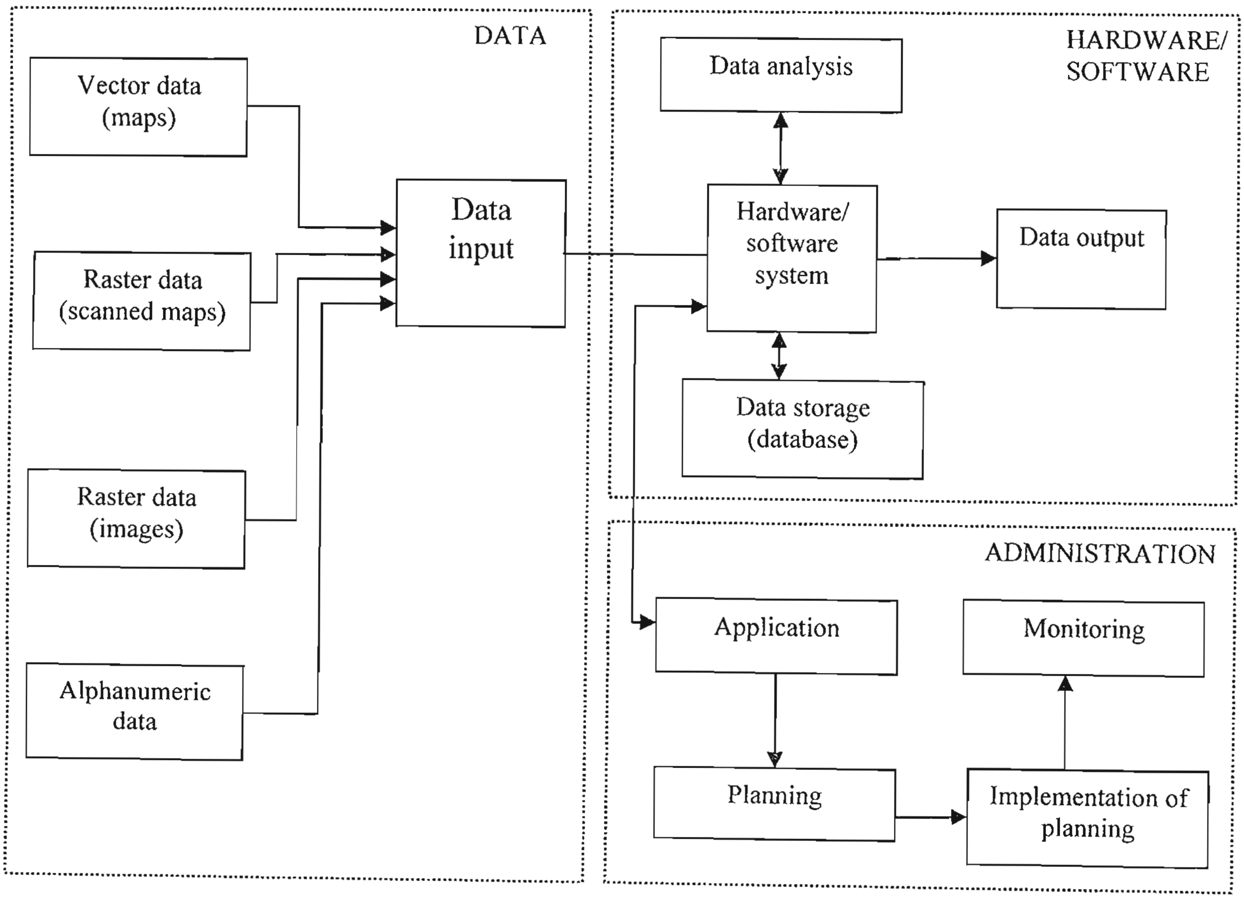

Figure 2.5: Concept of Geographic Information Systems (Konecny 2003).

To summarise, GIS are computer systems that are based on the inputting of spatial co-ordinates of either human or physical features on the earth's surface. The systems do not hold maps or pictures but rather hold a geographic database from which one can produce maps (Oellerman 2001), render explanations of distributional patterns of people, plants, animals, places and things, and predict new distributions and spatial arrangements through time (Demers 2000).

2.4.2 Remote Sensing

The study of the land is being and has been revolutionised through the introduction of many new techniques. These techniques allow for the continuous observation of any number of land features as well as the monitoring of land conditions. Remote sensing is just such a technique. Remote sensing is considered to be the identification or survey of objects by indirect means through the use of naturally existing or artificially created force fields and can be achieved either through the use of satellites or aircraft. The application of remote sensing techniques can provide information on the conditions of the land surface as a function of time (Bouma & Beek 1994; Sabins 1997). Remotely sensed information will often only reach its full potential when it is placed within a GIS, from which it can be interrogated and modelled in relation to other spatially distributed data (Light & Jensen 2002). The features of the earths surface can be categorised into, amongst others, either land cover or land use and both are discussed below.

Land Cover and Land use

There is no standard, universally accepted set of criteria for classifying or categorising land either by use or cover and ultimately it is the combination of both land use and cover that is widely utilised (Yemane 2003). Bibby and Shephard (1999) state that the representation and analysis of land cover has been a major area of GIS application since the introduction of the technology in the early 1970's and is widely utilised today. Land cover is the term associated with the physical appearance of the earth's surface and consists of classifiable terrain objects, whereas land-use assigns various categories according to the human use of the land and the economic benefits derived therefrom. The underlying concept of land-use is that it defines a social concept (Bibby & Shepherd 1999; Light & Jensen 2002; Konecny 2003) and it is important not to confuse the term 'land cover' with the term 'land use' as there are inherent differences between the two.

Land cover can be conceptualised as being the layer of soils and biomass, particularly vegetation that covers the earth's surface (Fresco 1994). Approximately 90% of the earth's land surface is covered by vegetation of some sort with more than half of the world's land cover consisting of cultivated land and pastures. Land use is the combined human action which affects land cover. Land cover has numerous functions in terms of biogeochemical cycles, the provision of food and shelter for humans as well as its landscapes and aesthetic value, whereas in contrast, land use is mankind's systematic way of changing land cover. Land cover is a constantly changing variable partly as a result of seasonal climatic variation but also as a result of human actions. A change in land cover can have an impact on a range of potential land uses in any given area whereas a change in land use can physically alter the land cover, either in terms of conversion or a modification (Thomson 1999). The massive land use conversions of the past two centuries have changed many natural systems, predominantly forests and savannas to agriculture and pasture with the resultant effect on wildlife only realised after the conversion (Lavers & Haines-Young1996). The most important land cover change, however, appears to be the intensification of land use through better management of production factors (Fresco 1994).

In order to monitor and understand the change and interaction of land cover and land use, Sabins (1997) illustrates the reasons that remote sensing techniques are becoming increasingly more important as tools for the mapping of land use and land cover. These include:

- Large areas can be imaged quickly and repeatedly,
- Images can be acquired with a spatial resolution that matches the required degree of detail,
- Remote sensing images often eliminate the associated problems of ground surveys,
- Image interpretation is faster and less expensive than conducting ground surveys and,
- Images provide an objective, permanent data set that may be interpreted for a wide range of specific land uses and land covers.

However, there are certain disadvantages to remote sensing surveys, namely:

- Certain land use types may not be distinguishable on images, and

- Most images lack the horizontal perspective that is valuable for the identification of many land use categories.

Land cover, identified through remote sensing, thus forms a reference base for a number of applications which include rangeland and forest monitoring, biodiversity, climate change and desertification control (Jansen & Di Gregorio 2002).

South African Land Cover Project

Until 1996, no single standardised land cover database existed for South Africa. However, the South African National Land Cover Database project was initiated in 1996 and completed by 1999. The primary motivation for this project was to create an accessible database (through the generation of appropriate maps) highlighting the present distributions and areas of South Africa's natural and altered land-cover types (Fairbanks & Thomson 1996; Thomson 1999). The data were generated from single date (1994), 1:250 000 scale hardcopy image-maps, using traditional photo-interpretation techniques, with a 25 ha minimum mapping unit and were based on LANDSAT Thematic mapper (TM) satellite imagery (Thompson, 1999; Thompson, van den Berg, Newby & Hoare 2001).

The 2000 National Land Cover (NLC) project, which is still to be finalised, has been mapped at a more refined scale of 1:50 000 during 2000 and 2001 with a minimum mapping unit of 1ha, with data that have been acquired through high resolution, digital satellite imagery, Landsat 7 ETM. The reason for this is that one of the key objectives of the NLC 2000 is to increase in spatial detail at a national level. The final product of the NLC 2000, it is hoped, will be a significantly improved, second generation land cover product, with enhanced spatial detail and content (Thompson *et al.* 2001).

2.4.3 GIS Data

The application of GIS within the environmental arena will ultimately result in the usage of data from a variety of sources including, remotely sensed imagery (satellite imagery and aerial photographs), field data collected by GPS[2] technology, digital data

---

[2] Global Positioning System refers to the use of satellites to ascertain a relative position on the earth through real-time navigation (Konecny 2003)

and hardcopy maps, which include amongst others, species distributions, land use/land cover data, climatic and weather data and terrain representations. Spatial data is currently represented in two basic data models within the GIS environment, namely the raster and vector data models. Raster-based systems record the spatial information as a series of points in a network grid of cells (pixels). These pixels represent the smallest independent unit of common information. Vector-based systems represent data using a geometry of continuous space to position points, lines and areas or polygons (Burrough 1986; Woodcock *et al.* 1990). Vector-based models allow for spatial data to be represented with definite linear dimensions and are thus a more precise alternative to raster-based models.

Although most applications utilise a wide array of data, both in scale and source, GIS are able to integrate these data sources in a variety of applications. The limitation, however, regarding environmental data within GIS is that many landscape features and natural phenomena do not display distinct homogenous boundaries and so their representation on a map can be somewhat limited. It is imperative that users of such data are aware of the possible limitations (e.g. data quality, accuracy and/ or precision, sampling density) and are aware that its usage and outputs are dependant on the particular application. The development of data standards and metadata is, however, helping to improve the use of such data, as are the advancements in data processing and analysis (McMaster & McMaster 2002).

2.4.4 GIS and Environmental Problem Solving

The most successful application of GIS is in the addressing of environmental problems (Goodchild 1993). Ecological systems play a fundamental role in supporting life on earth at all levels, including mankind. They form the life-support system without which economic activity would not be possible. Mankind's ability to alter these economic and ecological systems, often to their detriment, and the rate of spread of the impacts of these alterations, is far faster than mankind's ability to predict the full extent of these impacts (Vitousek, *et al.* 1997). Protecting and preserving mankind's natural life-support systems requires the ability to understand the direct and indirect effects of human activities over long periods of time and over large areas. Computer simulations are now becoming important tools to investigate these interactions (Maxwell *et al.* undated; Wakelin 2001). Concurrently, managers of natural resources have always been primarily focused on the managing of identified areas in a sustainable manner, yet it is only within the last 10 to 15 years that such managers have recognised the benefits of utilising GIS to support spatial analysis of natural resources and thereby enhancing their management efforts (McMaster & McMaster 2002). GIS are able to depict data in both a visual and analytical context and these systems have enormous benefits as they have the ability to handle spatial data in a manner that is precise, rapid and sophisticated (Oellermann 2001).

GIS have been used in a number of environmental fields, including habitat identification and protection, environmental monitoring and change detection, natural resource management, conservation planning, impact analysis and environmental modelling (Woodcock *et al.* 1990, McMaster & McMaster 2002). Although it is beyond the scope of this research to analyse the benefits of GIS within the various environmental fields, it is important to understand that GIS contribute to a wide range of environmental arenas. The use of GIS in supporting biophysical applications is undoubtedly set to expand and improve as firstly, advancements are made in both data and analytical procedures and secondly, as research continues to improve society's understanding of how scale influences ecological processes and how such processes are modelled (McMaster & McMaster 2002).

2.4.5 The Use of GIS and Crane Conservation

Understanding the distribution of animals within a certain area is a basic requirement for many ecological and conservation studies (Austin, Thomas, Houston & Thompson 1996) and as such a number of studies pertaining to cranes have been undertaken utilising GIS, including one by Kanai, Kondoh and Higuchi (1994) who investigated the breeding, resting and wintering habitat of Red-crowned (*Grus japonensis*), White-naped (*Grus vipio*) and Hooded Cranes (*Grus monacha*) utilising satellite imagery. Ronchini (1998) investigated whether or not the loss of Wattled Crane nest sites was influenced by the nature and status of the surrounding land cover. The 1996 land cover dataset was used and the present study will attempt a similar investigation utilising updated land cover data and home range requirements. Herr and Queen (1993) used GIS in modelling suitable crane habitat used by the Greater Sandhill

Crane (*Grus canadensis tabida*), the results of which indicated that certain pairs utilised sub-optimal habitat despite the apparent availability of optimal habitat. This phenomenon could be accounted for in the data and modelling approach and certain unanswered questions pertaining to the birds' behaviour. Such findings reinforce the importance of understanding the data utilised within GIS and the particular application. Baker, Cade, Mangus and McMillen (1995) investigated the utilisation of habitat by Greater Sandhill Cranes at multiple spatial scales and it was concluded that there was no habitat selection beyond 200m from a nest and it was recommended that judicious management of the existing habitat could, in all likelihood, increase nest density yet could potentially be detrimental to other species. Timoney (1999), through a spatial, multi-scale approach compared available habitat with that of habitat already utilised by Whooping Cranes (*Grus americana*) within the Wood Buffalo National Park, Canada. The study concluded that the Wood Buffalo-Aransas crane population utilised only a small proportion of the total available habitat and that the population would not be limited by the availability of breeding habitat in the near future.

2.5 CONCLUSION

The Wattled Crane within South Africa is dependant on the private landowner for its survival. The protection of its habitat, namely grasslands and wetlands, needs urgent attention and the destruction of which cannot continue unabated. A set of acceptable management guidelines for the remaining Wattled Crane areas needs to be implemented so as to ensure that existing territories are conserved in perpetuity. The landscapes of today within which the Wattled Crane currently exists have been formed as a consequence of the current agricultural practices. Modern agricultural techniques have resulted in the cultivation of larger parcels of land, which are more easily managed than irregular shaped ones, resulting in fewer areas available for the biodiversity that can occur within the agricultural landscape. A new approach to conventional conservation outside formally protected areas needs to be developed which effectively links the areas managed by farmers, the plantations managed by foresters and the protected areas managed especially for biodiversity (McNeely & Scherr 2003). Agricultural production systems should complement the surrounding natural environments and thereby enhance the ecosystem functions. GIS provide the spatial tools that enable users to comprehensively manipulate data, perform numerous spatial analyses such that the result is a high quality cartographic output which thus aids in the protection of biodiversity on privately owned land. The integration of GIS, with conservation friendly management practices within the agricultural landscape and current conservation programmes is crucial if the Wattled Crane is to survive well into the 21^{st} Century.

3. MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter details and describes the proposed methods to be utilised and the approach that will be adopted in order to achieve the objectives set out in Chapter one. A number of techniques will be utilised using GIS to analyse the land cover and associated patch configuration within the home ranges of active, historical and existing Wattled Crane nest sites. Figure 3.1 illustrates the process that will be utilised in this study.

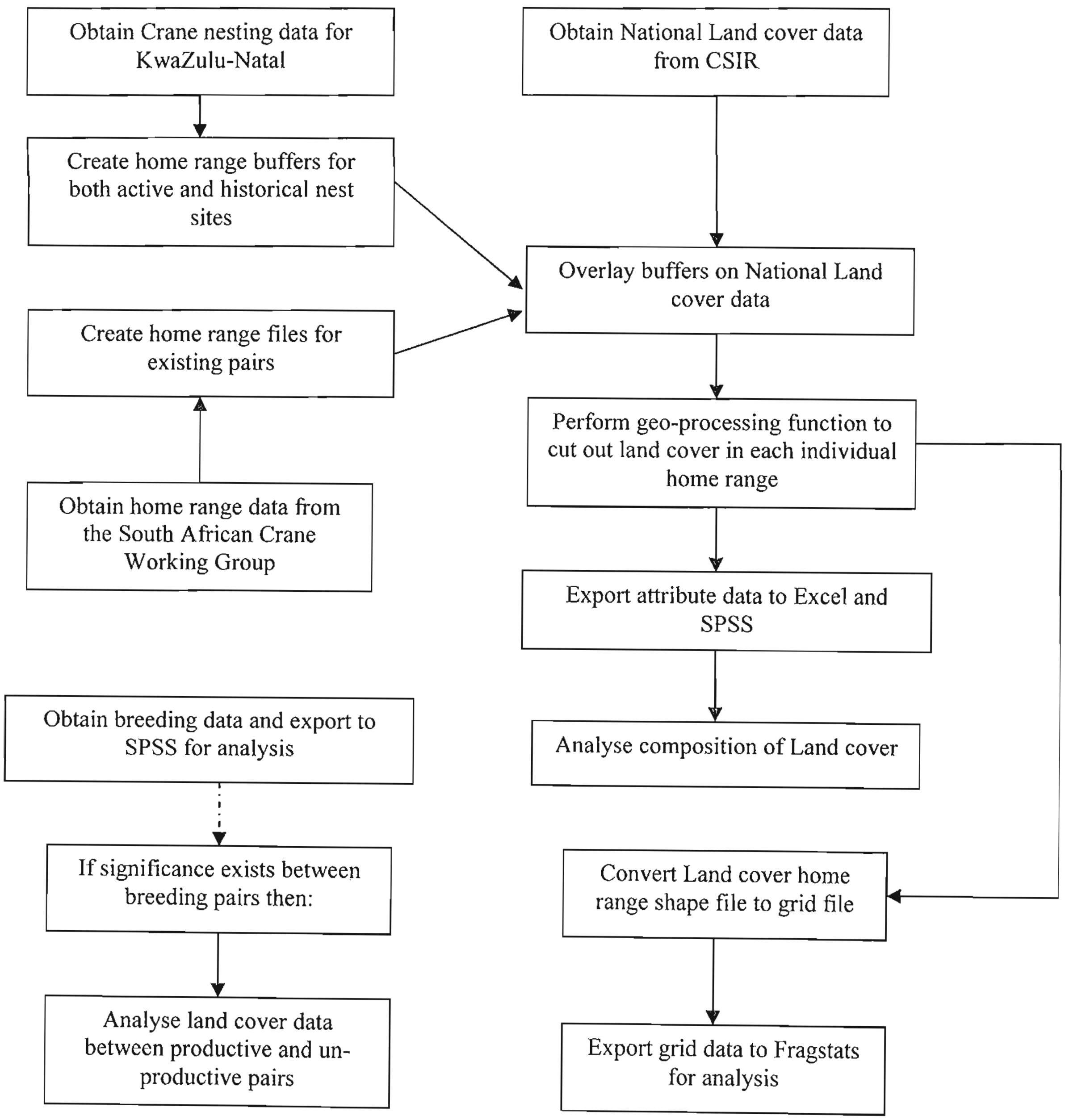

Figure 3.1: Flow chart of the methods to be utilised in this study.

3.2 STUDY AREA

The study area will be located in the province of KwaZulu-Natal, from Greytown (29^0 03'S; 30^0 35'E) in the East through Mooi River (29^0 12'S; 29^0 43'E) and then southwards towards Underberg (29^0 47'S; 29^0 29'E), including Kamberg (29^0 22'S; 29^0 43'E) and Nottingham Road (29^0 21'S; 29^0 59'E). The area includes six nature reserves: the Stillerust section of the Kamberg Nature Reserve (29^0 22'S; 29^0 43'E), uMngeni Vlei Nature Reserve (29^0 28'S; 29^0 48'E), Highmoor Nature Reserve (29^0 19'S; 29^0 37'E), Midmar Nature Reserve (29^0 29'S; 30^0 11'E), Himeville Nature Reserve (29^0 44'S; 29^0 31'E) and Coleford Nature Reserve (29^0 57'S; 29^0 27'E). Figure 3.2 illustrates the location of the study area.

The landscape of the KwaZulu-Natal midlands is dominated by an array of agricultural and commercial afforestation transformation. Common agricultural operations include livestock enterprises, whilst much cultivation of maize, potatoes and vegetables is interspersed. Irrigated lands that are utilised either for fodder production or year-round dairy feed are also common in the area, whilst *Pinus* and *Eucalyptus* spp are the forestry species of choice. (McCann & Benn *in press*). The extent of this transformation and habitat modification is greater than in any other country or than in any other province within southern Africa and it is estimated that 25% of the province is currently transformed (Scott-Shaw 1999).

3.3 WATTLED CRANE DATA

A total of 93 Wattled Crane pairs will be selected for the purpose of this study. The data will comprise longitudinal and latitudinal locations (in decimal degrees) of all 93 pairs, which data have been collected over the past 10 years through various members of staff of the KwaZulu-Natal Crane Foundation (KZNCF), South African Crane Working Group (SACWG) and Ezemvelo KwaZulu-Natal Wildlife. This data will include 55 active breeding pairs, where the term 'active' indicates some attempt at breeding over the preceding five year period and 43 historical breeding sites, where the term 'historical' indicates that the pairs have not been recorded in the breeding territory for longer than five years (up until the period in which the land cover data was compiled i.e. 2000). The active nest sites that will be chosen in no way constitute all the current active sites, of which there are currently 70, for KwaZulu-Natal. Those nest sites that occur on the periphery of the distribution range of the Wattled Crane within KwaZulu-Natal will not be selected for the purpose of this study and thus 85% of all active nest sites will be analysed for this study. Of the 55 historical sites that have been recorded for the province, 78% will be utilised during this study.

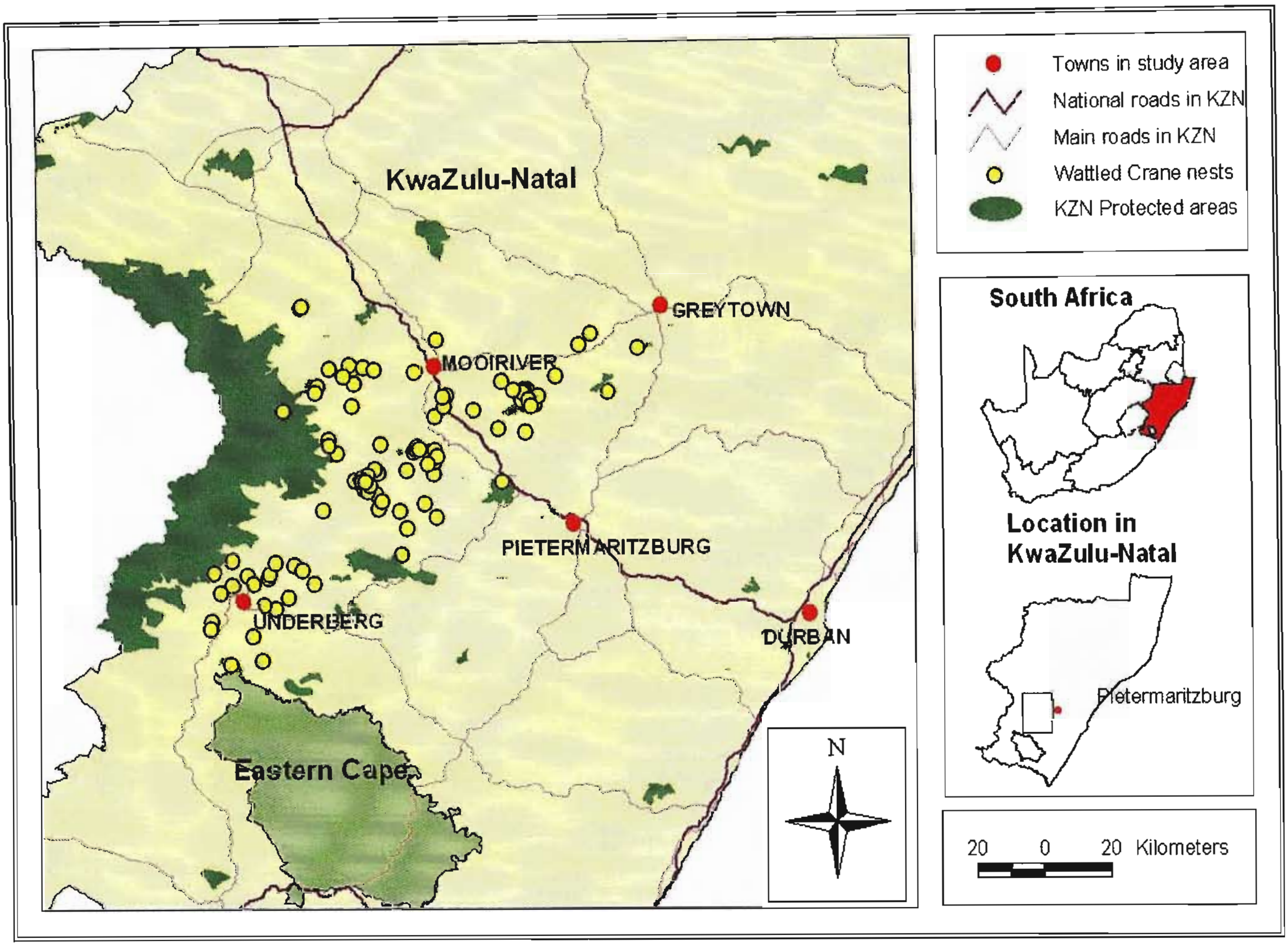

Figure 3.2: Location of the study area in the midlands of KwaZulu-Natal, South Africa, showing the locations of the major towns and reserves.

3.3.1 Wattled Crane Home Range Calculation

This study will attempt to analyse two components of the land cover composition. Firstly, the latest land cover information (National Land Cover 2000) will be analysed within the estimated home range of each pair of Wattled Cranes which range has been calculated at 16.26km^2 (McCann & Benn *in press*), with the nest being regarded as the centre of the home range and secondly, the land cover within the actual known home range sizes for 38 Wattled Crane pairs (Appendix 1) will be analysed. McCann and Benn (*in press*) has calculated these home ranges through individual pair observations and each individual sighting location having been recorded. These observations and recordings were then analysed utilising ArcView Animal Movement Analysis ArcView Extension (USGS-BRD, Alaska Biological Science Centre) to compile the home range for each individual pair. Thus, the difference between active and exisitng refers to the size of the home range where the home range around active sites is the estimate, whilst the home range around the exisiting sites is the actual home range for that particular pair. Therefore in the analyses, some sites will be analysed twice.

The Buffer function in Arcview 3.2 (ESRI, Redlands, California) will be utilised to create buffer zones around each of the nest sites to represent the estimated home range, where the nest sites will be taken to represent the central point of each home range. The following equation will be utilised in calculating the buffer radii:

Home Range

$$\text{Area (circle)} = \Pi r^2$$

$$\text{therefore } r = \sqrt{(\text{area} / \Pi)}$$

$$r = \sqrt{(16.26 / \Pi)}$$

$$r = 2.275\text{km}$$

The composition of the various land cover classes will be analysed within the three categories of home ranges viz. active, historic and existing, utilising SPSS11.5 for Windows so as to ascertain whether or not the land cover composition of a Wattled Crane's home range will lead to site abandonment. Subsequent to these analyses, the land cover within each home range will be subjected to further scrutiny. This will include investigation of the variance of patch size, perimeter-area ratio, distance between patch types and distance from the nest to the various patch types.

3.3.2 Breeding productivity

The SACWG and the KZNCF have actively monitored the breeding productivity of numerous Wattled Crane pairs across KwaZulu-Natal with an emphasis on areas within the midlands region. This study will attempt to analyse whether or not it is possible to determine whether certain pairs are more productive than other pairs. The data collected will be collated into tabular form and an indication will be given of whether a chick was fledged or not. The data will be analysed utilising SPSS 11.5 for Windows to ascertain if there is a significant difference in the breeding productivity of the various pairs. Breeding data on a total of 20 pairs will be analysed, with the breeding success calculated as hatching success x fledgling success. The data that have been collected are limited to 20 pairs (included in Appendix 1), of which the majority are those pairs that are easily accessible. This has resulted in certain nests being monitored more frequently than others which could result in a bias in the results.

3.4 PILOT STUDY

One of the initial objectives of this study was to investigate the various management practices that occur within the home ranges of active Wattled Crane sites and then compare these to historical sites. To this effect, it was decided to initiate a pilot study to determine the feasibility of such an endeavour and whether or not suitable information could be obtained from the various landowners. A questionnaire was compiled (Appendix 2), and five landowners interviewed. Although the landowners were very receptive and forthcoming with management practices for their particular properties, the data collected were deemed to be inadequate as these would not prove suitable for analysis. Landowners were unable to provide accurate data to meet the requirements of the questionnaire because no accurate records are kept pertaining to burning regimes, planting times and irrigation. It was thus deemed appropriate to remove this objective from the study. As a result of having to remove this objective from the study, it was decided to investigate not only the composition of the home ranges but also the configuration.

Landscapes can be characterised by both their composition and configuration. These two aspects of the landscape can independently or in conjunction have an impact on ecological processes and organisms, particularly the Wattled Crane, occurring in such landscapes (McGarigal & Marks 1994). The term ‘landscape composition’ refers to the presence and amount of those features associated with each patch type, in this case, land cover type, yet without being spatially explicit. Thus, landscape composition encompasses the variety and abundance of patch types but not the location or placement of such patches within the landscape mosaic. In contrast, the term 'landscape configuration' refers to the spatial configuration of patch types in relation to not only one another but also to other features of interest.

Fragstats 3.3 allows the user to investigate the configuration of landscapes, however the data will have to be converted from vector land cover data to a raster format. This could potentially have an impact on the results as a result of the change in pixel size and would thus need to be considered during the interpretation of the results.

3.5 SOUTH AFRICA'S LAND COVER PROJECT

The land use/cover classification that will be used for this study is in accordance with the South African classification system, as defined by Thompson *et al.* (2001) (Appendix 3). However, of interest is that the land cover legend utilised during the original NLC database has been expanded within NLC 2000 to include more detailed sub-classes. This expansion has been achievable through the use of digital (rather than hard-copy), and multi-seasonal (rather than single-date) satellite imagery. For example, the NLC *Forest Plantation* class will now be subdivided into dominant genus types, i.e. *Pine*, *Eucalypt* and *Wattle* classes. The South African system is designed to suit the South Africa environment, yet simultaneously to conform to internationally accepted standards and conventions.

The Geo-processing function in ArcView will be utilised to 'cut out' the land cover within each of the estimated and actual home ranges. The attributes of each of the created shape files will then be exported to Microsoft Excel and SPSS 11.5 for further analysis. Such analyses may include, percentage composition of the various land cover types for both active and historical nest sites, size of patch types, and also perimeter-area ratio.

3.6 DATA ANALYSIS

The data, once exported to SPSS 11.5 that will be utilised in this study is not of a normal distribution. The response variable, i.e. the status of the Wattled Crane nest being either active or historical is of a binomial nature and thus Quinn and Keough (2002) recommend that logistical regression be utilised in the analysis of the data. Logistical regression analysis will be performed against the various land use categories, the composition of the home ranges, as calculated in Arc-View, the configuration of the home ranges, as calculated utilising Fragstats and the distance of the various land classes from each nest site. This form of analysis will allow for either an acceptance or rejection of the null hypothesis. The null hypothesis is that there is no difference in land cover composition and configuration between active and historical nesting sites.

The data, once analysed will be represented graphically and in tabular format. The nature of the data may result in a number of tables which will be included as appendices.

REFERENCES

BIBLIOGRAPHY

ABREY, A.N. 1992. The Wattled Crane: Hatching and Raising in Captivity. In: PORTER; D.J., CRAVEN; H.S., JOHNSON, D.N. and PORTER, M.J. (eds.). *Proceedings of the First South African Crane Conference*. Durban: The Southern African Crane Foundation.

ADIE, H. & GOODMAN, P.S. 2000. Grasslands. In: GOODMAN, P.S. (ed). *Determining the conservation value of land in KwaZulu-Natal.* Final report. Biodiversity division, KwaZulu-Nature conservation services, Pietermaritzburg.

AUSTIN, G.E., THOMAS, C.J., HOUSTON, D.C. & THOMPSON, D.B.A. 1996. Predicting the spatial distribution of buzzard *Buteo buteo* nesting areas using a Geographical Information System and remote sensing. *Journal of Applied Ecology* (33): 1541-1550.

BAKER, B.W., CADE, B.S., MANGUS, W.L. & McMILLEN, J.L. 1995. Spatial Analysis of Sandhill Crane nesting habitat. *Journal of Wildlife Management* 59 (4): 752-758.

BARLOWE, R. 1978. *Land resource Economics: The Economics of Real Estate*. 3rd ed. New Jersey: Prentice-Hall.

BARNES, K.N. 2000. *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland.* Johannesburg: Birdlife South Africa.

BEGG, G. 1990. The wetlands of Natal (Part 4): policy proposals for the wetlands of Natal and KwaZulu. *Natal Town and Regional Planning report* 75.

BEILFUSS, R.D. & ALLAN, D.G. 1996. Wattled crane and wetland surveys in the great Zambezi Delta, Mozambique. In: BEILFUSS, R.D., TARBOTON, W.R. & GICHUKI, N.N. (eds). *Proceedings 1993 African Crane and Wetland Training Workshop*. Baraboo, International Crane Foundation.

BENTON, T.G., BRYANT, D.M., COLE, L. & CRICK, H.Q.P. 2002. Linking agricultural practice to insect and bird populations: a historical study over three decades. *Journal of Applied Ecology* 39: 673-687.

BIBBY, P.R. & SHEPHERD, J.W. 1999. Monitoring land cover and land use for urban and regional planning. In: LONGLEY, P.A., GOODCHILD, M.F., MAQUIRE, D.J. & RHINDS, D.W. (eds). *Geographical Information Systems.* 2nd Ed Vol 2. London: Wiley & Sons.

BOISE, C. 1976. Breeding Biology of the Lesser Sandhill Crane – A Preliminary report. In: LEWIS, J.C. (ed). Proceedings of the International Crane Workshop, Oklahoma State University.

BOUMA, J. & BEEK, K.J. 1994. New techniques and Tools. In: FRESCO, L.O., STROOSNIJDER, L., BOUMA, J. & van KEULEN, H. (eds.). *The future of the land: Mobilising and integrating knowledge for land-use options.* West Sussex: John Wiley & Sons Ltd.

BOUTIN, C., FREEMARK, K.E. & KIRK, D.A. 1999. Farmland birds in southern Ontario: field use, activity patterns and vulnerability to pesticide use. *Agriculture, Ecosystems and Environment* 72: 239-254.

BROOKE, R. K. & VERNON, C. J. 1988. Historical records of the Wattled Crane (*Bugeranus carunculatus*) (*Gmelin*) in the Cape Province and the Orange Free State, South Africa. *Annuals of the Cape Provincial Museum of Natural History* 16: 363-371.

BRIGGS, D.J. & COURTNEY, F.M. 1989. *Agriculture and Environment. The Physical Geography of Temperate Agricultural systems.* Singapore: Longmore.

BURKE, A. 1996. Wattled Crane (*Bugeranus carunculatus*).In: MEINE, C.D. and ARCHIBALD, G.W (eds). *The Cranes: Status, survey and Conservation Action Plan.* Gland: IUCN.

BURROUGH, P.A. 1986. *Principles of Geographic Information Systems for land resources assessment.* Monographs on soil and resources survey, Oxford.

BYLIN, K. 1987. The Common Crane in Sweden – Distribution, Numerical Status, Habitats, Breeding Success and Need of Protection. In: ARCHIBALD, G.W. and PASQUIER, R.F. (eds.). *Proceedings of the 1983 International Crane Workshop*, Baraboo: International Crane Foundation.

COVERDALE, B.M. & McCANN, K.I. 2003. Breeding age and pair formation of Wattled Cranes, *Bugeranus carunculatus,* in the wild. *Ostrich* 74 (3&4): 226-227.

DEL HOYO, J. 1992. Family GRUIDAE (CRANES) In: DEL HOYO, J. & ELLIOT, A. (eds). *Handbook of the birds of the world. Volume 3.* Barcelona, Lynx Edicions.

DEMERS, M.N. 2000. *GIS modelling in Raster*. New York: Wiley & Sons.

DÍAZ, M., GONZÁLEZ, E., MUÑOZ-PULIDO, R. & NAVESO, M.N. 1996. Habitat selection patterns of Common Cranes *Grus grus* wintering in Holm Oak *Quercus ilex* dehesas of central Spain: Effects of human management. *Biological Conservation* 75 (2): 119-123.

DICKENS, C., KOTZE, D., MASHIGO, S., MACKAY, H. & GRAHAM, M. 2003. *Guidelines for Integrating the Protection, Conservation and Management of Wetlands into Catchment Management Planning*. WRC Report No. TT220/04.

DOUTHWAITE, R.J. 1974. An Endangered Population of Wattled Cranes (*Grus carunculatus*). *Biological Conservation* 6 (2): 134-142.

FAIRBANKS, D.H. & THOMSON, M.W. 1996. Assessing land-cover map accuracy for the South African Land-Cover Database. *South African Journal of Scicence* (92): 465-470.

FILMER, R.J. & HOLTSHAUSEN, G.R. 1992. The Southern African Crane Census, 1985/1986. In: PORTER, D.J., CRAVEN, H.S., JOHNSON, D.N. & PORTER, M.J. (eds.). *Proceedings of the First South African Crane Conference*. Durban: The Southern African Crane Foundation.

FINLAYSON, M. & MOSER, M. (eds.). 1991. Wetlands. International Waterfowl and Wetlands Research Bureau. Oxford: Facts on File Ltd.

FRESCO, L.O. 1994. Imaginable futures: A contribution to thinking about land use planning. Introductory chapter. In: FRESCO, L.O., STROOSNIJDER, L., BOUMA, J. & van KEULEN, H. (eds.). *The future of the land: Mobilising and integrating knowledge for land-use options*. West Sussex: John Wiley & Sons Ltd.

GALL, G.A.E. & ORIANS, G.H. 1992. Agriculture and Biological Conservation. *Agriculture, Ecosystems and Environment* 42 (1): 1-8.

GILL, J.A., SUTHERLAND, W.J. & WATKINSON, A.R. 1996. A method to quantify the effects of human disturbance on animal populations. *Journal of Applied Ecology* 33: 786-792.

GILPIN, M., GALL, A.E. & WOODRUFF, D.S. 1992. Ecological dynamics and agricultural landscapes. *Agriculture, Ecosystems and Environment* 42 (1): 27-52.

GOODCHILD, M.F. 1993. The State of GIS for Environmental Problem-Solving. In: GOODCHILD, M.F.; PARKS, B.O. and STEYAERT, L.T. (eds.). *Environmental Modeling with GIS.* New York: Oxford University Press.

GUZMÁN, J.M.S., GARCÍA, A.S., AMADO, C.C. & DEL VIEJO, A.M. 1999. Influence of farming activities in the Iberian Peninsula on the winter habitat use of Common Crane (*Grus grus*) in areas of its traditional migratory routes. *Agriculture, Ecosystems and Environment* 72: 207-214.

HALLADAY, P. & GILMOUR, D.A. (eds.). 1995. *Conserving Biodiversity Outside Protected Areas. The role of traditional agro-ecosystems.* IUCN, Gland, Switzerland and Cambridge, UK.

HANEY, J.C. & EISWERTH, M.E. 1992. The plight of cranes: A case study for conserving biodiversity. In: STAHLECKER, D.W. (Ed). *Proceedings of the Sixth North American Crane Workshop.* Baraboo: International Crane Foundation.

HARRIS, J. 1994. Cranes, People and Nature: Preserving the balance. In: HIGUCHI, H. & MINTON, J. (eds.). The Future of Cranes and Wetlands. *Proceeding of the International Symposium*, Tokyo, Wild Bird Society of Japan.

HERR, A.M. & QUEEN, L.P. 1993. Crane habitat evaluation using GIS and remote sensing. *Photogammetric engineering and remote sensing* 59 (10): 1531-1538.

HIETALA-KOIVU, R. 2002. Landscape and modernising agriculture: a case study of three areas in Finland in 1954-1998. *Agriculture, Ecosystems and Environment* 91: 273-281.

JANSEN, L.J.M. & DI GREGORIO, A. 2002. Parametric land cover and land-use classification as tools for environmental change detection. *Agriculture, Ecosystems and Environment* (91): 89-100.

JOHNSGARD, P. A. 1983. *Cranes of the World.* Bloomington: Indiana University Press.

JOHNSON, D.N. 1992. Extent and reasons for crane population declines. In: PORTER, D.J., CRAVEN, H.S., JOHNSON, D.N. and PORTER, M.J. (eds.). *Proceedings of the First South African Crane Conference.* Durban: The Southern African Crane Foundation.

JOHNSON, D.N. & BARNES, P. R. 1991. The breeding biology of the wattled crane in Natal. In: HARRIS, J. (ed). *Proceedings of the 1987 International Crane Workshop.* Baraboo: International Crane Foundation.

JONES, K.L., RODWELL, L., McCANN, K., VERDOORN, G. & ASHLEY, M.V. 2001. Genetic status of Wattled Cranes in south-central Africa. *Ostrich* Supplement 15: 23.

KANAI, Y., KONDOH, A. & HIGUCHI, H. 1994. Analysis of crane habitat using satellite images. In: HIGUCHI, H. & MINTON, J. (eds.). The Future of Cranes and Wetlands. *Proceeding of the International Symposium*, Tokyo, Wild Bird Society of Japan.

KIRKMAN, K.E. & POTT, R. McC. 2002. Biodiversity Conservation in Plantation Forestry. In: PIERCE, S.M., COWLING, R.M., SANDWITH, T. & MACKINNON, K. (eds.). *Mainstreaming Biodiversity in Development – Case Studies from South Africa.* Washington: The World Bank.

KONECNY, G. 2003. *Geoinformation. Remote sensing, photogrammetry and geographic information systems.* London: Taylor & Francis.

KONRAD, P. M. 1981. Status and ecology of the wattled crane in Africa. In: LEWIS, J.C. and MASATOMI, H. *Crane Research Around the World 1980 Proceedings of the International Crane Symposium.* Baraboo: International Crane Foundation.

KOTZE, D.C. & BREEN, C.M. 1994. Agricultural land-use impacts on wetland functional values. WRC Report No 501/3/94. Pretoria: Water Research Commission.

LACHER, T.E., Jr., SLACK, R.D., COBURN, L.M. & GOLDSTEIN, M.I. 1999. The Role of Agroecosystems in Wildlife Biodiversity. In: COLLINS, W.W. & QUALSET, C.O. (eds.). 1999. *Biodiversity in Agroecosystems.* Florida: CRC Press LLC.

LAVERS, C.P. & HAINES-YOUNG, R.H. 1996. Using models of bird abundance to predict the impact of current land-use and conservation policies in the flow country of Caithness and Sutherland, Northern Scotland. *Biological Conservation* 75 (1): 71-77.

LIGHT, D.L. & JENSEN, J.R. (2002). Photogrammetric and remote sensing considerations. In: BOSSLER, J.D. (Ed). *Manual of Geospatial Science and Technology.* London: Taylor & Francis.

LIYING, S. 1993. *Comparative feeding ecology of the Red-crowned and White-naped Cranes*. Unpublished MA Thesis, University of Missouri – Columbia.

LOCKHART, J.A.R. & WISEMAN, A.J.L. 1988. *Introduction to Crop Husbandry including grassland.* 6th ed. Oxford: Pergamon press.

LOW, A.B. & REBELLO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

MALAN, G. & BENN, G.A. 1999. Agricultural land-use patterns and the decline of the helmeted guineafowl *Numida meleagris* (Linnaeus 1766) in KwaZulu-Natal, South Africa. *Agriculture, Ecosystems and Environment* 73: 29-40.

McCANN, K., & WILKINS, H. 1995. A study of the annual biology and movement patterns of the three crane species in the Kwa-Zulu Natal Midlands. Eskom and Endangered Wildlife Trust Environmental Impact Assessment.

McCANN, K.I. 2000a. Briefing Book – Wattled Crane Population, habitat and Viability Analysis. Endangered Wildlife Trust.

McCANN, K.I. 2000b. Wattled Crane *Bugeranus carunculatus*. In: BARNES, K.N. (ed). *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland.* Johannesberg: Birdlife South Africa.

McCANN, K.I. 2001. Population status of South Africa's three crane species as of the end of 1999: based on a National Crane Census and regional aerial surveys. Ostrich Supplement 15: 126-129.

McCANN, K.I., SHAW, K., ANDERSON, M.D. & MORRISON, K. 2001. Techniques for determining movement patterns of Blue and Wattled Cranes in South Africa – colour-ringing versus satellite telemetry. *Ostrich* Supplement 15: 104-108.

McCANN, K.I. 2002. Using Wattled Cranes as an indicator of the hydrological functioning of,and threats to palustrine wetlands in South Africa. In Bernard, T., K. Mosepele & L. Ramberg (ed.). *Environmental monitoring of tropical and subtropical wetlands*: 92.

McCANN, K.I. & BENN, G. *In press*. Land use patterns within Wattled Crane (*Bugeranus carunculatus*) home ranges in an agricultural landscape in the KwaZulu-Natal province, South Africa.

McGARIGAL, K. & MARKS, B.J. 1994. *Fragstats: Spatial Pattern analysis program for quantifying landscape structure*. Oregon State University, Corvalis.

McNEELY, J.A. 1995. How traditional agro-ecosystems can contribute to conserving biodiversity. In: HALLADAY, P. & GILMOUR, D.A. (eds.). 1995. *Conserving Biodiversity Outside Protected Areas. The role of traditional agro-ecosystems*. IUCN, Gland, Switzerland and Cambridge, UK.

McNEELY, J.A. & SCHERR, S.J. 2003. *Ecoagriculture – Strategies to Feed the World and Save Biodiversity*. Wahsington D.C. Future Harvest, IUCN & Island Press.

McMASTER, S. & McMASTER, R.B. 2002. Biophysical and human-social applications. In: BOSSLER, J.D. (ed.). *Manual of Geospatial Science and Technology*. London, Taylor & Francis.

MEINE, C. D. & ARCHIBALD, G.W. (eds.). 1996. *The Cranes – Status, Survey and Conservation Action Plan*. Gland: IUCN.

MONDI WETLAND PROJECT. 2000. *Practical Wetland Management*. Wildlife and Environment Society of South Africa, South Africa.

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

MORRISON, K & BOTHMA, J. du P. 1998. Wetland nesting sites of wattled and grey crowned cranes on the Steenkampsberg Plateau, South Africa. *South African Journal of Wildlife Research* 28(4): 110-120.

NEKE, K.S. & DU PLESSIS, M.A. 2004. The Threat of Transformation: Quantifying the Vulnerability of Grasslands in South Africa. *Conservation Biology* 18 (2): 466-477.

NEWTON, I. 1998. *Population limitation in birds*. London: Academic Press Limited.

OBERMEYER, N.J. & PINTO, J.K. 1994. *Managing Geographic Information Systems*. New York: The Guilford Press.

O'CONNOR, R.J. & SHRUBB, M. 1986. *Farming and Birds*. London: Cambridge University Press.

OELLERMANN, C.G. 2001. *Land Use analysis using GIS: A case study of Richards Bay Minerals' Zulti South mining lease area*. Unpublished MSc Thesis. Pietermaritzberg, University of Natal.

ORIANS, G.H. & LACK, P. 1992. Arable Lands. *Agriculture, Ecosystems and Environment* 42 (1-2): 101-124.

PIENKOWSKI, M.W. & BIGNAL, E.M. 1993. Objectives for nature conservation in European agriculture. In: DIXON, J.B., STONES, A.J. & HEPBURN, I.R. (eds.). A future for Europe's farmed countryside (Proceedings of an international conference. Studies in European Agriculture and Environment Policy, No. 1). RSPB, Sandy, Bedfordshire: 21-43. Cited in: PIENKOWSKI, M.W., BIGNAL, E.M., GALBRAITH, C.A., McCRACKEN, D.I., STILLMAN, R.A., BOOBYER, M.G. & CURTIS, D.J. 1996. A Simplified classification of land-type zones to assist the integration of biodiversity objectives in land-use policies. *Biological Conservation* 75(1): 11-25.

PIENKOWSKI, M.W., BIGNAL, E.M., GALBRAITH, C.A., McCRACKEN, D.I., STILLMAN, R.A., BOOBYER, M.G. & CURTIS, D.J. 1996. A Simplified classification of land-type zones to assist the integration of biodiversity objectives in land-use policies. *Biological Conservation* 75(1): 11-25.

PIPER, J.K. 1999. Natural Systems Agriculture. In: COLLINS, W.W. & QUALSET, C.O. (eds.). 1999. *Biodiversity in Agroecosystems*. Florida: CRC Press LLC.

QUINN, G.P. & KEOUGH, M.J. 2002. *Experimental design and data analysis for Biologists*. London: Cambridge University Press

RATCLIFFE, C.S. & CROWE, T.M. 2001. Declining populations of Helmeted Guineafowl in the midlands of KwaZulu-Natal, South Africa: a review of causes and remedies. *South African Journal of Wildlife Research* 31(3&4): 161-171.

RIVERS-MOORE, N.A. 1997. *The use of a Geographic Information System to examine land use patterns in the Midmar catchment.* Unpublished MSc Thesis, Pitermaritzburg, University of Natal.

RONCHINI, S. 1998. *The impacts of land use changes on Wattled Crane breeding sites.* Masters thesis. School of Environment and Development, University of Natal, Pietermartizburg.

SABINS, F.F. 1997. *Remote Sensing: Principles and interpretation.* 3rd ed. New York: W.H. Freeman and Co.

SACWG 2004. South African Crane Working Group – A working group of the Endangered Wildlife Trust. Available at: www.ewt.org.za/cranes. Accessed: 20th April 2004.

SCOTT-SHAW, C.R. 1999. *Rare and Threatened Plants of KwaZulu-Natal and neighbouring regions*. Pitermaritzburg, KwaZulu-Natal Nature Conservation Service.

SOUTHWOOD, T.R.E. & CROSS, D.J. 1969. The ecology of the partridge. III. Breeding success and the abundance of insects in natural habitats. *Journal of Applied Ecology* 38: 497-509. Cited in: TAPPER, S.C., POTTS, G.R. & BROCKLESS, M.H. 1996. The effect of an experimental reduction in predation pressure on the breeding success and population density of grey partridges *Perdix perdix*. *Journal of Applied Ecology* 33(5): 965-978.

STARÝ, P. & PIKE, K.S. 1999. Uses of Beneficial Insect Diversity in Agroecosystem Management. In: COLLINS, W.W. & QUALSET, C.O. (eds.). 1999. *Biodiversity in Agroecosystems*. Florida: CRC Press LLC.

TARBOTON, W.R. 1984. The status and conservation of the wattled crane in the Transvaal. In: LEDGER, J. (ed). *Proceedings of the 5th Pan African Ornithological Congress*. Johannesburg, South African Ornithological Society.

TARBOTON, W.R., BARNES, P.R. & JOHNSON, D.N. 1987. The Wattled Crane in South Africa during 1978-1982. In: ARCHIBALD, G.W. & PASQUIER, R.F. (eds.). *Proceedings of the 1983 International Crane Workshop*, Baraboo: International Crane Foundation.

TIVY, J. 1990. *Agricultural Ecology*. Essex, Longman Group UK.

TEKELENBURG, A., PRYDATKO, V., ALKEMADE, J.R.M., SCHAUB, D., LUHMANN, E. & MEIJER, J.R. UNDATED. Assessment of Wild Biodiversity in Agricultural Land Use. First design and perspectives of a pressure-based Global Biodiversity Model. Available at: http://www.ulrmc.org.au/publication/envmanag/globio%20rivm%20ulrmc.pdf. Accessed: 16 September 2004.

THOMPSON, M.W. 1999. *South African National Land-Cover Database Project: Data Users Manual*. Final Report (Phase 1, 2 & 3). Division of Water, Environment and Forest Science, CSIR.

THOMPSON, M.W., VAN DEN BERG, H.M., NEWBY, T.S. & HOARE, D. 2001. *Guideline Procedures for National Land-cover mapping and change monitoring*. Version 2. Terrestrial Resources and Environmental Management, CSIR and Agricultural Research Council. Available at:

http://www.csir.co.za/websource/ptl0002/images/environmentek/nlc2000/appendices/25558-1.pdf. Accessed: 03 June 2005

TIMONEY, K. 1999. The habitat of nesting whooping cranes. *Biological Conservation* 89: 189-197.

TUXILL, J. 1998. Losing Strands in the Web of Life: Vertebrate declines and the Conservation of Biological Diversity. *Worldwatch paper 141*

URBAN, E.K. & DAVENPORT, L.B. Jr. 1993. Time of Nesting in wild and captive Wattled Cranes Bugeranus carunculatus. *Proceedings of the 8th Pan-African Ornithilogical Congress.* 405-409.

VAN DER WERF, H.M.G. & PETIT, J. 2002. Evaluation of the environmental impact of agriculture at the farm level: a comparison and analysis of 12 indicator-based methods. *Agriculture, Ecosystems and Environment* 93: 131-145.

VAN DUIVENBOODEN, N. 1995. Land Use systems analysis as a tool in land use planning, with special reference to North and West African agro-ecosystems. PhD Thesis, Wageningen Agricultural University, Wageningen, The Netherlands.

VERNON, C. J. & BOSHOFF, A. F. 1986. The status and conservation of the wattled crane (*Grus carunculatus)* in the Cape Province and Transkei. *Bontebok* 5: 37-41.

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 South African Crane Conference*. Durban: The Southern African Crane Foundation.

VITOUSEK, P.M., MOONEY, H.A., LUBCHENCO, J. & MELILLO, J.M. 1997. Human Domination of Earth's Ecosystems. Science 277: 494-499.

WAKELIN, J. 2001. The impact of land transformation on breeding Blue Swallows *Hirundo atrocaerulea* Sundevall in KwaZulu-Natal. Unpublished BSc Honours Thesis. Pietermaritzburg: University of Natal.

WALKINSHAW, L. 1965. The wattled crane (*Bugeranus carunculatus)* (Gmelin). *The Ostrich* 36: 73-81.

WARNER, R.E. 1994. Agricultural Land Use and Grassland Habita in Illinois: Future Shock for Midwestern Birds? *Conservation Biology* 8 (1): 147-156.

WARREN, A. & FRENCH, J.R. 2001. Relations between Nature Conservation and the Physical Environment. In; WARREN, A. & FRENCH, J.R. (eds.). Habitat Conservation: Managing the physical environment. West Sussex, Wiley & Sons.

WEST, O. 1963. Notes on the Wattled Crane *Bugeranus carunculatus* (Gmelin). *Ostrich* (34): 63-77.

WEST, O. 1976. Notes on the distribution and status of the southern population of wattled cranes in Africa. In: LEWIS, J.C. (ed). *Proceedings of the International Crane Workshop.* Norman: Oklahoma State University.

WOODCOCK, C.E., SHAM, C.H. and SHAW, B. 1990. Comments on Selecting a Geographic Information System for Environmental Management. *Environmental Management* 14 (3): 307-315.

YEMANE, M.M. 2003. *An Assessment of Changes in Land Use/Cover Patterns in the Albert Falls Area, KwaZulu-Natal, South Africa.* Unpublished MSc Thesis, Pietermaritzburg, University of Natal.

PERSONAL COMMUNICATIONS

McCANN, K.I. 2004. Interview. 20 July at KZNCF headquarters.

APPENDICES

APPENDIX 1: WATTLED CRANE NESTS TO BE USED IN THE STUDY

FARM_NAME	STATUS	MAP_REF	MAP_NAME	SOUTH			EAST			DECIMAL DEGREES	
				Deg	Min	Sec	Deg	Min	Sec	Latitude	Longitude
Active sites											
Aldora*	Active	2930 AC	Howick	29	22	0	30	15	0	-29.36667	30.25000
Alida Mount (Craigie Burn)*	Active	2930 AB	Mount Alida	29	13	25	30	19	50	-29.22361	30.33056
Arlington / Fairfield	Active	2930 AC	Howick	29	21	25	30	10	40	-29.35694	30.17778
Boston View	Active	2930 CA	Merrivale	29	34	45	30	0	45	-29.57917	30.01250
Briar lea	Active	2929 DA	Himeville	29	43	25	29	30	20	-29.72361	29.50556
Broadmoor*	Active	2929 BB	Estcourt	29	12	10	29	47	35	-29.20278	29.79306
Burnside (Jacksons)*	Active	2930 AC	Howick	29	15	57	30	13	55	-29.26583	30.23194
Chestnuts*	Active	2929 BD	Nottingham Rd	29	28	10	30	0	15	-29.46944	30.00417
Dieu Donne Lifton	Active	2929 CB	Sani Pass	29	41	5	29	28	0	-29.68472	29.46667
Dublin	Active	2929 DA	Himeville	29	43	50	29	33	50	-29.73056	29.56389
Falkirk	Active	2929 BB	Estcourt	29	14	30	29	47	40	-29.24167	29.79444
Fordoun*	Active	2930 AC	Howick	29	19	35	30	0	35	-29.32639	30.00972
Forest Lodge*	Active	2929 BA	Ntabamhlope	29	14	45	29	41	50	-29.24583	29.69722
Grafton	Active	2929 BB	Estcourt	29	11	35	29	46	53	-29.19306	29.78139
Glamoor**	Active	2929 BD	Nottingham Rd	29	24	44	29	57	10	-29.41222	29.95278
Highlands	Active	2929 CD	Underberg	29	50	20	29	24	30	-29.83889	29.40833
Highlands 2	Active	2929 CD	Underberg	29	51	30	29	24	25	-29.85833	29.40694
Highmoor	Active	2929 BC	Kamberg	29	18	30	29	36	15	-29.30833	29.60417
Hopewell*	Active	2929 BD	Nottingham Rd	29	24	45	29	59	50	-29.41250	29.99722
Hutton 1	Active	2929 BB	Estcourt	29	12	0	29	49	15	-29.20000	29.82083
Impendle Loc	Active	2929 DB	Impendle	29	33	30	29	51	30	-29.55833	29.85833
Ivanhoe top	Active	2929 DB	Impendle	29	31	10	29	51	5	-29.51944	29.85139
Kilmun	Active	2929 DC	Pevensey	29	56	30	29	32	35	-29.94167	29.54306

* Nest sites for which breeding data have been collected

Lake Lyndhurst 1	Active	2929 BD	Nottingham Rd	29	28	5	29	51	25	-29.46806	29.85694
Marwaqa	Active	2929 DA	Himeville	29	44	50	29	41	10	-29.74722	29.68611
Melmoth 1	Active	2930 AD	Albert Falls	29	17	50	30	16	30	-29.29722	30.27500
Melmoth 2	Active	2930 AD	Albert Falls	29	17	25	30	16	10	-29.29028	30.26944
Middledraai*	Active	2930 AC	Howick	29	17	5	30	14	30	-29.28472	30.24167
Middleton	Active	2930 AB	Mount Alida	29	7	5	30	25	35	-29.11806	30.42639
Mt Le Sueur	Active	2929 DA	Himeville	29	33	35	29	42	35	-29.55972	29.70972
Mt Shannon*	Active	2929 DB	Impendle	29	40	20	29	55	0	-29.67222	29.91667
Nutbrook*	Active	2929 BD	Nottingham Rd	29	27	40	29	56	0	-29.46111	29.93333
Oaklands	Active	2930 AA	Weston	29	7	55	30	0	50	-29.13194	30.01389
Oaksprings*	Active	2930 AA	Weston	29	14	15	30	11	15	-29.23750	30.18750
Potatoes*	Active	2929 BC	Kamberg	29	15	45	29	41	30	-29.26250	29.69167
Rock farm*	Active	2929 BD	Nottingham Rd	29	23	40	29	51	55	-29.39444	29.86528
Rondebosch / Honeydew*	Active	2930 AC	Howick	29	16	15	30	2	20	-29.27083	30.03889
Scawby	Active	2930 AD	Albert Falls	29	15	30	30	15	25	-29.25833	30.25694
Shawlands*	Active	2929 BD	Nottingham Rd	29	24	30	29	57	35	-29.40833	29.95972
Shawlands 1 (Wetland)*	Active	2929 BD	Nottingham Rd	29	24	4	29	57	39	-29.40111	29.96083
Shawlands 2 (Quarry)	Active	2929 BD	Nottingham Rd	29	24	21	29	58	7	-29.40583	29.96861
Southdown	Active	2929 BD	Nottingham Rd	29	26	15	30	0	25	-29.43750	30.00694
Stadlers Rust[*]*	Active	2929 BB	Estcourt	29	13	20	29	46	5	-29.22222	29.76806
Stille Rust*	Active	2929 BC	Kamberg	29	23	0	29	43	40	-29.38333	29.72778
The Praires	Active	2929 BD	Nottingham Rd	29	17	50	29	47	25	-29.29722	29.79028
Top Overbury	Active	2929 BD	Nottingham Rd	29	27	30	29	50	50	-29.45833	29.84722
Top Umgeni	Active	2929 BD	Nottingham Rd	29	29	10	29	47	42	-29.48611	29.79500
uMngeni Vlei 1	Active	2929 BD	Nottingham Rd	29	29	0	29	48	40	-29.48333	29.81111
uMngeni Vlei 2	Active	2929 BD	Nottingham Rd	29	28	50	29	48	50	-29.48056	29.81389
uMngeni Vlei 3	Active	2929 BD	Nottingham Rd	29	28	55	29	49	15	-29.48194	29.82083
Umvoti	Active	2930 BA	Greytown	29	9	20	30	33	0	-29.15556	30.55000

[*] Nest sites for which breeding data have been collected

Winchester**	Active	2929 BB	Estcourt	29	12	20	29	50	55	-29.20556	29.84861
Woodhouse 2a	Active	2929 DB	Impendle	29	30	25	29	49	10	-29.50694	29.81944
Woodhouse 2c	Active	2929 DB	Impendle	29	30	45	29	49	50	-29.51250	29.83056
Woodhouse 2f/g)	Active	2929 DB	Impendle	29	29	49	29	50	4	-29.49694	29.83444
Historical sites (no longer used)											
Arlington	Historic	2930 AC	Howick	29	18	41	30	6	43	-29.31139	30.11194
Abingdon	Historic	2929 DA	Himeville	29	43	15	29	34	0	-29.72083	29.56667
Balmoral	Historic	2930 AD	Albert Falls	29	16	30	30	17	0	-29.27500	30.28333
Banavie	Historic	2929 DC	Pevensey	29	52	40	29	31	10	-29.87778	29.51944
Blinkwater	Historic	2930 AD	Albert Falls	29	16	0	30	28	15	-29.26667	30.47083
Burnside 1	Historic	2930 AC	Howick	29	15	30	30	14	50	-29.25833	30.24722
Burnside 2	Historic	2930 AC	Howick	29	16	0	30	14	35	-29.26667	30.24306
Coleford NR	Historic	2929 CD	Underberg	29	57	0	29	27	40	-29.95000	29.46111
Conemara 2	Historic	2930 AC	Howick	29	24	40	30	0	30	-29.41111	30.00833
Conemara 1	Historic	2930 AC	Howick	29	25	30	30	0	50	-29.42500	30.01389
Dargavel	Historic	2929 BC	Kamberg	29	25	0	29	44	50	-29.41667	29.74722
Dartmoor	Historic	2930 AD	Albert Falls	29	17	0	30	15	30	-29.28333	30.25833
Dartmoor 2	Historic	2930 AC	Howick	29	17	0	30	15	35	-29.28333	30.25972
Elgin	Historic	2929 CB	Sani Pass	29	44	55	29	28	0	-29.74861	29.46667
Glenlea	Historic	2929 DC	Pevensey	29	48	30	29	35	0	-29.80833	29.58333
Himeville NR	Historic	2929 DA	Himeville	29	44	40	29	31	20	-29.74444	29.52222
Ivanhoe bottom	Historic	2929 DB	Impendle	29	32	20	29	52	5	-29.53889	29.86806
Kildare	Historic	2930 AC	Howick	29	18	0	30	2	0	-29.30000	30.03333
Lake Lyndhurst 2	Historic	2929 BD	Nottingham Rd	29	28	20	29	49	50	-29.47222	29.83056
Lynton Trevalan	Historic	2929 DC	Pevensey	29	48	0	29	33	0	-29.80000	29.55000
Melmoth	Historic	2930 AD	Albert Falls	29	18	0	30	15	55	-29.30000	30.26528
Midmar NR	Historic	2930 AC	Howick	29	29	30	30	11	0	-29.49167	30.18333
Mount Park	Historic	2929 DB	Impendle	29	32	45	29	58	45	-29.54583	29.97917
Pasture Research 2	Historic	2929 BA	Ntabamhlope	29	2	50	29	39	20	-29.04722	29.65556

* Nest sites for which breeding data have been collected

Pasture Research 1	Historic	2929 BA	Ntabamhlope	29	2	40	29	39	30	-29.04444	29.65833
Rainbow Lakes	Historic	2929 DB	Impendle	29	33	50	29	54	50	-29.56389	29.91389
Reekie Lynn	Historic	2929 BC	Kamberg	29	23	50	29	43	40	-29.39722	29.72778
River Lea	Historic	2929 CD	Underberg	29	46	0	29	26	10	-29.76667	29.43611
Rondebosch	Historic	2930 AC	Howick	29	16	30	30	1	55	-29.27500	30.03194
Scafell	Historic	2929 CB	Sani Pass	29	43	0	29	25	0	-29.71667	29.41667
Sessay	Historic	2929 DA	Himeville	29	42	0	29	38	0	-29.70000	29.63333
Southdowns 2	Historic	2930 AC	Howick	29	26	45	29	59	20	-29.44583	29.98889
Summerhill	Historic	2929 BB	Estcourt	29	12	40	29	57	20	-29.21111	29.95556
The Duffryn	Historic	2929 DA	Himeville	29	41	30	29	35	0	-29.69167	29.58333
The Swamp	Historic	2929 DC	Pevensey	29	46	45	29	36	55	-29.77917	29.61528
Tweefontein	Historic	2930 AC	Howick	29	15	30	30	13	10	-29.25833	30.21944
uMngeni Vlei 4	Historic	2929 BD	Nottingham Rd	29	29	10	29	49	5	-29.48611	29.81806
uMngeni Vlei 5	Historic	2929 BD	Nottingham Rd	29	29	15	29	48	45	-29.48750	29.81250
uMngeni Vlei 6	Historic	2929 BD	Nottingham Rd	29	29	15	29	49	30	-29.48750	29.82500
Umvoti Heights (Corries Ru	Historic	2930 AB	Mount Alida	29	8	45	30	23	35	-29.14583	30.39306
Upton	Historic	2929 DA	Himeville	29	42	40	29	39	20	-29.71111	29.65556
West Hastings	Historic	2929 DB	Impendle	29	36	25	29	55	55	-29.60694	29.93194
Yorkville	Historic	2929 BA	Ntabamhlope	29	12	10	29	43	50	-29.20278	29.73056
Existing Sites (calculated home ranges)											
Arlington	Historic	2930 AC	Howick	29	18	41	30	6	43	-29.31139	30.11194
Blinkwater	Historic	2930 AD	Albert Falls	29	16	0	30	28	15	-29.26667	30.47083
Boston View	Active	2930 CA	Merrivale	29	34	45	30	0	45	-29.57917	30.01250
Briar lea	Active	2929 DA	Himeville	29	43	25	29	30	20	-29.72361	29.50556
Broadmoor	Active	2929 BB	Estcourt	29	12	10	29	47	35	-29.20278	29.79306
Chestnuts	Active	2929 BD	Nottingham Rd	29	28	10	30	0	15	-29.46944	30.00417
Dieu Donne Lifton	Active	2929 CB	Sani Pass	29	41	5	29	28	0	-29.68472	29.46667
Falkirk	Active	2929 BB	Estcourt	29	14	30	29	47	40	-29.24167	29.79444
Fordoun	Active	2930 AC	Howick	29	19	35	30	0	35	-29.32639	30.00972
Forest Lodge	Active	2929 BA	Ntabamhlope	29	14	45	29	41	50	-29.24583	29.69722

Grafton	Active	2929 BB	Estcourt	29	11	35	29	46	53	-29.19306	29.78139
Highlands	Active	2929 CD	Underberg	29	50	20	29	24	30	-29.83889	29.40833
Hopewell	Active	2929 BD	Nottingham Rd	29	24	45	29	59	50	-29.41250	29.99722
Hutton 1	Active	2929 BB	Estcourt	29	12	0	29	49	15	-29.20000	29.82083
Jacksons	Active	2930 AC	Howick	29	15	57	30	13	55	-29.26583	30.23194
Lake Lyndhurst 1	Active	2929 BD	Nottingham Rd	29	28	5	29	51	25	-29.46806	29.85694
Marwaqa	Active	2929 DA	Himeville	29	44	50	29	41	10	-29.74722	29.68611
Middledraai	Active	2930 AC	Howick	29	17	5	30	14	30	-29.28472	30.24167
Mt Shannon	Active	2929 DB	Impendle	29	40	20	29	55	0	-29.67222	29.91667
Oaksprings	Active	2930 AA	Weston	29	14	15	30	11	15	-29.23750	30.18750
Potatoes	Active	2929 BC	Kamberg	29	15	45	29	41	30	-29.26250	29.69167
Rock farm	Active	2929 BD	Nottingham Rd	29	23	40	29	51	55	-29.39444	29.86528
Rondebosch / Honeydew	Active	2930 AC	Howick	29	16	15	30	2	20	-29.27083	30.03889
Scawby	Active	2930 AD	Albert Falls	29	15	30	30	15	25	-29.25833	30.25694
Shawlands	Active	2929 BD	Nottingham Rd	29	24	30	29	57	35	-29.40833	29.95972
Southdown	Active	2929 BD	Nottingham Rd	29	26	15	30	0	25	-29.43750	30.00694
Stadlers Rust	Active	2929 BB	Estcourt	29	13	20	29	46	5	-29.22222	29.76806
Stille Rust	Active	2929 BC	Kamberg	29	23	0	29	43	40	-29.38333	29.72778
The Praires	Active	2929 BD	Nottingham Rd	29	17	50	29	47	25	-29.29722	29.79028
Top Overbury	Active	2929 BD	Nottingham Rd	29	27	30	29	50	50	-29.45833	29.84722
Top Umgeni	Active	2929 BD	Nottingham Rd	29	29	10	29	47	42	-29.48611	29.79500
Umgeni Vlei 1	Active	2929 BD	Nottingham Rd	29	29	0	29	48	40	-29.48333	29.81111
Umgeni Vlei 2	Active	2929 BD	Nottingham Rd	29	28	50	29	48	50	-29.48056	29.81389
Umgeni Vlei 3	Active	2929 BD	Nottingham Rd	29	28	55	29	49	15	-29.48194	29.82083
Winchester	Active	2929 BB	Estcourt	29	12	20	29	50	55	-29.20556	29.84861
Woodhouse 2a	Active	2929 DB	Impendle	29	30	25	29	49	10	-29.50694	29.81944
Woodhouse 2c	Active	2929 DB	Impendle	29	30	45	29	49	50	-29.51250	29.83056
Woodhouse 2f/g)	Active	2929 DB	Impendle	29	29	49	29	50	4	-29.49694	29.83444

APPENDIX 2: SURVEY QUESTIONNAIRE

Survey to assess the management practices and land uses within Wattled Crane (*Bugeranus carunculatus*) home ranges and the potential impact on breeding productivity.

Brent M. Coverdale

Masters in Environment and Development: Environmental Management

Centre for Environment and Development – University of KwaZulu-Natal

Notes:

1. This information will be used to determine impacts, if any, on breeding productivity and if possible suggest management guidelines best suited to breeding productivity.
2. This questionnaire is in no way intended to comment on farming practices but rather if these practices impact on Wattled Crane breeding productivity.
3. Where necessary, place a tick in the appropriate box.

Section A: Contact Details

Landowner name :	Title :	
	First name :	
	Surname :	
	Period on property:	
Address :		
	Postal code :	
Contact details :	Telephone :	
	Fax :	
	Cell phone :	
	Email	
Property Name :		
Map sheet reference : (1:50 000 or 1 : 250 000 sheet)		
Province :		
Region :		
District :		
GPS co-ordinates :	S ° ' " / E ° ' "	
Farm size (hectares) :	Ha	

Land status / ownership:	Privately-owned :		Nature reserve :		
	Forestry land :		Other :		
	If other, describe :				
Main farming operation:	Dairy :		Beef :		
	Small stock :		Crops :		
	Vegetables :		Game :		
	Mixed :		Other :		
Main Farming Operation (additional notes or description) :					

Section B: Wattled Crane information

What Crane habitat exists on the farm :						
Wetlands :		Grasslands :		Farm dams :		
Agricultural lands :		Other :		Specify, if other :		
WATTLED CRANE SITES :						
Do Wattled Cranes breed on your property? YES / NO						
Number of breeding pairs?						
Nest site Name(s) :						
How long have they bred on the property?						
GPS Coordinates of nest site : S ° ' " / E ° ' "						
If not, do Wattled Cranes forage on your property? YES / NO						
If Yes, what time of year: Numbers:						
WATTLED CRANE PRODUCTIVITY						
Do you monitor the Wattled Cranes on your farm? YES / NO						
If yes, do you know if they have:						
Breed in:	Yr 1999	Yr 2000	Yr 2001	Yr 2002	Yr 2003	
Hatched successfully in:	Yr 1999	Yr 2000	Yr 2001	Yr 2002	Yr 2003	

If not have they renested in:	Yr 1999	Yr 2000	Yr 2001	Yr 2002	Yr 2003
Fledged Successfully in:	Yr 1999	Yr 2000	Yr 2001	Yr 2002	Yr 2003

Section C: Land-use management

CROP MANAGEMENT:

If crops are grown, please indicate type

Type	Hectare	Season[1]		Rotation[2]	Irrigated	
		Period	Duration		Yes	No
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

[1]= Time of the year between planting and harvesting and duration in months
[2]= Cycle between each crop, expressed in years

What agrochemicals are used on your crops?

Chemical	Purpose	Application method[1]	Intensity	No of applications

[1]= please also list man hours to apply as hrs/ha

PASTURE MANAGEMENT:

Type	Hectare	Usage	Season[1]		Rotation[2]	Irrigation	
			Period	Duration		Yes	No
1.							
2.							
3.							
4.							
5.							

1= Time of year of planting and duration of pasture
2= Frequency of rotation of pasture

IRRIGATION:

What method of irrigation is used on the property?

Centre Pivot		Drag line		Dry land		Other	

Are irrigation types, crop specific? YES / NO

If yes, please specify

Crop/ pasture type	Irrigation type
1.	
2.	
3.	
4.	
5.	
6.	

Duration of irrigation:

Hrs per day		Days per week		Weeks per year	

Centre pivot: Describe movement of pivot during cycle i.e. revolutions?

Drag lines: Describe movement of lines i.e. how often lines are moved?

Other, please describe?

HARVESTING:

Please describe your methods of harvesting?

Crop type	Method	Duration[1]	Season[2]
1.			
2.			
3.			
4.			
5.			
6.			

[1]= time required to harvest crop, expressed as hours / hectare
[2]= time of the year when harvesting takes place

LAND PREPARATION

Month (s) of year that land is prepared:

Briefly describe the process involved:

Man hours expended to prepare land:

What agrochemicals are utilised at this stage?

Chemical	Purpose

PLANTING:

What is the time period required to plant each crop?

Crop type	Duration[1]	Season[2]	Method

[1]= time required to plant crop expressed as days/ha
[2]= time of the year that crop is planted

What agrochemicals are utilised at this stage?

Chemical	Purpose

BURNING: FIREBREAKS

Please indicate the location of firebreaks on the map provided?

Please explain the preparations needed prior to firebreaks?
Preparation of tracer lines:
Chemicals:

Type of chemical	Duration to prepare	Time of year

Mow

Tractor man hours	Duration to prepare	Time of year

Other:

What month (s) of the year are breaks burnt?

What is the time required to burn breaks?

0-1 hr	1-2 hrs	2-3 hrs	3-4 hrs	4-5 hrs	5-6 hrs	6-7 hrs	7-8 hrs

BURNING: BLOCKS

Please indicate burning blocks on the map provided?

What month (s) of the year are blocks burnt?

Burning regime of wetland:

1999		2000		2001		2002		2003	
Month	Burnt	Month	Burnt	Month	Burnt	Month	Burnt	Month	Burnt

Is your wetland burnt as a firebreak? YES / NO

CROP DAMAGE :

Do you have problems with Crane Crop Damage ? YES / NO

Crop type	Species	Numbers	Time of year (* indicate the months of the year they are present)	Degree of damage **

** Codes for the Degree of Damage : SL = Slight damage, ME = Medium damage, HE = Heavy damage, SE = Severe damage

GRAZING:
Please describe your grazing management? In terms of rotation, rest period and intensity?   What is the stocking rate, expressed as AU/ha?

Please indicate the number of camps utilised on the map provided?

Camp number (ID)	Time of year utilised	1999	2000	2001	2002	2003

Do you graze your wetland? YES / NO

NATURAL VELD:

Do you make hay from your veld? YES / NO

1999		2000		2001		2002		2003	
Freq[1]	D/tion[2]	Freq	D/tion	Freq	D/tion	Freq	D/tion	Freq	D/tion

[1]= how many time shay is made
[2]= how long it takes to make and remove, expressed as hrs / ha

Section D: Other management practices

PREDATORS:
Do you have predators on the property? YES / NO
Type of predators that exist?
Do you actively control predators? YES / NO
Does poaching occur on your farm? YES / NO
Do you feel that Wattled Crane chicks are targeted? YES / NO

Have you caught anyone with a crane chick?	YES	/	NO
If yes, when: ______________________________			
Level of impact on breeding productivity from predators			
Negligible θ	Low θ	Moderate θ	High

POWERLINE INCIDENTS :					
Have you had powerline incidents on farm ?	YES / NO				
Type of incident :	COLLISION / ELECTROCUTION				
Powerlines on farm :	11 kV		22 kV		
	33 kV		66 kV		
	88 kV		132 kV		
	220 kV		275 kV		
	400 kV				

NEST LOCATION:

Proximity of nest to:

Roads	Fields	Buildings	Fences
Dams	Labour movement	Other (Please describe)	

Level of impact from human disturbance (including farming activity, vehicle traffic, human pathways, deliberate disturbance) :			
Negligible θ	Low θ	Moderate θ	High
Notes :			

Section E: Any other information

Please feel free to express any comments or ideas that you may feel are relevant to the success of Wattled Crane breeding productivity and their conservation?

APPENDIX 3: LAND COVER CLASSES (THOMSON ET AL. 2001)

Recommended Minimum Legend Structure for Preferred Stratification Level (~ 1:50,000 scale)

No	Land Cover Class	Definition
1	Forest (indigenous)	All wooded areas with a tree canopy > 70 %. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forests (and woodlots)
2	Forest & Woodland (*rename* as Woodland)	All wooded areas with a tree canopy between 10 - 70%. A broad sparse - open – closed canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forests (and woodlots) Canopy cover density classes may be mapped if desired, based on sparse (< 40%), open (40 – 70 %), and closed (> 70 %).
3	Thicket, Bushland, Bush Clumps, High Fynbos	Communities typically composed of tall, woody, self-supporting, single or multi-stemmed plants (branching at or near the ground), with, in most cases no clearly definable structure. Total canopy cover is greater than 10%, with canopy heights between 2 – 5 metres. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species, especially along riparian zones). Presence of alien exotic species can be modelled spatially using broad principles of unlikely structural / temporal occurrences within a given vegetation biome or region. Dense bush encroachment would be included in this category. Canopy cover density classes may be mapped if desired, based on sparse (< 40%), open (40 – 70 %), and closed (> 70 %).
4	Shrubland and Low Fynbos	Communities dominated by low, woody, self supporting, multi-5stemmed plants, branching at or near the ground, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are low Fynbos, Karoo and Lesotho (alpine) communities.
5	Herbland	Communities dominated by low, woody, non-grass like plants, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are found in Namaqualand or "weed" dominated degraded areas.
6	Unimproved (natural) Grassland	All areas of grassland with < 10% tree and/or shrub canopy cover, and >0.1% total vegetation cover Dominated by grass like non woody rooted herbaceous plants *Essentially indigenous species growing under natural or semi-natural conditions*.
7	Improved Grassland	As above, except .... *Planted grassland, containing either indigenous or exotic species, growing under man-managed (including irrigated) conditions for grazing, hay or turf production, recreation (i.e. golf) etc*
8	Forest Plantations (Eucalyptus spp)	All areas of systematically planted, man-managed tree resources, composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials and woodlot / windbreaks of sufficient size to be identifiable on satellite imagery. Excludes all non-timber based plantations such as tea, sisal, citrus, nut crops etc.
9	Forest Plantations (Pine spp)	
10	Forest Plantations (Acacia spp)	
11	Forest Plantations (Other / mixed spp)	

12	Forest Plantations (clearfelled)	
13	Waterbodies	Areas of (generally permanent) open water. The category includes both natural and manmade waterbodies, which are either static or flowing, and fresh, brakish and salt water conditions. This category includes features such as rivers, major reservoirs, farm-level irrigation dams, permanent pans, lakes and lagoons.
14	Wetlands	Natural or artificial areas where the water level is permanently or temporarily at (or very near) the land surface, typically covered in either herbaceous or woody vegetation cover. The category includes fresh, brakish and salt water conditions. Examples include pans (with nonpermanent water cover), and reed-marsh or papyrus-swamp.
15	Bare Rock and Soil (natural)	Natural areas of exposed sand, soil or rock with no, or very little vegetation cover during any time of the year, (excluding agricultural fields with no crop cover, and open cast mines and quarries). Examples would include rock outcrops, beach sand, and dry river bed material.
16	Bare Rock and Soil (erosion : dongas / gullies)	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of current gully erosion processes. Typically located in association with areas of poor grassland cover along existing streamlines and / or on slightly steeper slopes than sheet erosion areas (i.e. greater than 6 degree slope). In some areas the full extent of donga activity may be obscured by either overhanging adjacent bushes, encroaching thorn bush, or, in the case of more stable dongas, by bush or grass cover along the actual streamline.
17	Bare Rock and Soil (erosion : sheet)	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of current sheet erosion processes. Typically located in association with areas of severe donga erosion and / or poor grassland cover (i.e. low image NDVI rating). In some areas the full extent of this process may be
18	Degraded Forest & Woodland	Permanent or near-permanent, man-induced areas of very low vegetation cover (i.e. removal of tree, bush, or herbaceous cover) *in comparison to the surrounding natural vegetation cover.* Typically associated with subsistence level agriculture and rural population centres, where overgrazing of livestock and / or wood-resource removal has been locally excessive. Often associated with severe soil erosion problems.
19	Degraded Thicket, Bushland, etc	
20	Degraded Shrubland and Low Fynbos	
21	Degraded Herbland	
22	Degraded Unimproved (natural) Grassland	
23	Cultivated, permanent, commercial, irrigated	Areas of land that are ploughed and / or prepared for raising crops (excluding timber production). Unless otherwise stated, includes areas currently under crop, fallow land, and land being prepared for planting. Class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such all sub-classes may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks), as well as farm infrastructure Several sub-classes are defined, based on the following parameters : **Commercial** : characterised by large, uniform, well managed field units (i.e. ± 50 ha), with the aim of supplying both regional, national and export markets. Often highly mechanised. **Semi-Commercial** : characterised by small – medium sized field units (i.e. ± 10 ha), within an intensively cultivated site, often in close proximity to rural population centres. Typically based on multi-cropping activities where annual (i.e. temporary crops) are produced for local markets. Can be irrigated by either mechanical means or gravity-fed channels and furrows. Medium - low levels of mechanisation. **Subsistence** : characterised by numerous small field units (less than ± 10 ha) in close proximity to rural population centres. Field units can either be grouped either intensive or widely spaced, depending on the extent of the area under cultivation and the proximity to rural dwellings and grazing areas. Includes both rainfed and irrigated (i.e. mechanical or gravityfed), multi-
24	Cultivated, permanent, commercial, dryland	
25	Cultivated, permanent, commercial, sugarcane	
26	Cultivated, temporary, commercial, irrigated	
27	Cultivated, temporary, commercial, dryland	
28	Cultivated, temporary, subsistence,	

	dryland	cropping of annuals, for either individual or local (i.e. village) markets. May include fallow and 'old fields', and some inter-field grazing areas (which are often classified as degraded). **Permanent** Crops : lands cultivated with crops that occupy the area for long periods and are not re-planted after harvest. Examples would include sugar cane and citrus orchards. Note in the case of sugar can, the growing season is typically 15 – 18 months per ratoon (i.e. harvest), with 2 – 3 ratoons possible before re-planting. Sugar cane is mapped as a separate crop type, and includes both large and small scale commercial activities, as well as fallow (i.e. burnt /cleared) areas. **Temporary** Crops : land under temporary crops (i.e. annuals) that are harvested at the completion of the growing season, and that will remain idle until re-planted. In general this refers to maize and soya bean cultivation within the Pongola catchment, although cotton is locally dominant amongst the larger commercial sugar cane plantation areas. Irrigated / Non-Irrigated : major irrigation schemes (i.e. areas supplied with water for agricultural purposes by means of pipes, overhead sprinklers, ditches or streams), and are often characterized
29	Cultivated, temporary, subsistence, irrigated	
30	Urban / Built-up (residential)	Formal built-up areas, in which people reside on a permanent or near-permanent basis, identifiable by the high density of residential and associated infrastructure. Includes both towns, villages, and where applicable, the central nucleus of more open, rural clusters. Unless otherwise specified (and or mapped), will include both residential, commercial, industrial and transportation land-uses as well. Low density smallholdings frequently located on the urban fringe are mapped as a separate sub-classes, subdivided by the appropriate (level I) background vegetation type. If visible, individual farm units are also mapped as isolated smallholding units.
31	Urban / Built-up (rural cluster)	Areas of clustered rural dwellings (i.e. kraals) whose structural density is too low to be classified as a formal village, but are of sufficient level to be easily identifiable as such on satellite imagery. Small scale cultivation / garden plots often form a major spatial component, and are located amongst the residential structures.
32	Urban / Built-up (residential, formal suburbs)	Permanent residential structures, either single or multi-level, located within new or well established residential areas, i.e. '*garden-suburbs*', (often refers to 'middle-class' and 'upper class' residential areas). Includes both low and high building densities.
33	Urban / Built-up (residential, flatland)	Permanent residential structures, consisting mainly of 3 or more levels (often up to 10), resulting in a concentration of mid-to-high rise building, for example Hillbrow (Jhb) or Sunnyside (Pta).
34	Urban / Built-up (residential, mixed)	mixture …
35	Urban / Built-up (residential, hostels)	Permanent residential structures, typically located in formal township districts, consisting mainly of 1 or 2 levels in concentrated block-like structures.
36	Urban / Built-up (residential, formal township)	Permanent (i.e. brick etc) structures (predominately single level), usually located on serviced sites within former black residential areas, laid out in a organised, pre-planned manner. Includes both low and high building densities.
37	Urban / Built-up (residential, informal township	Permanent / semi-permanent shack type dwellings (i.e. corrugated tin structures) laid out and established in an organised, pre-planned manner on both serviced and non-serviced sites. Includes both low and high building densities
38	Urban / Built-up (residential, informal squatter camp)	Non-permanent shack type dwellings (i.e. tin, cardboard, wood etc) typically established on an informal, adhoc basis, on non-serviced sites. Typically high building densities
39	Urban / Built-up (smallholdings, woodland …)	see "residential' definition above ...
40	Urban / Built-up (smallholdings, thicket, bushland …)	see "residential' definition above ...
41	Urban / Built-up (smallholdings, shrubland …)	see "residential' definition above ...

42	Urban / Built-up (smallholdings, grassland ...)	see "residential' definition above ...
43	Urban / Built-up, (commercial, mercantile)	Non-residential areas used primarily for the conduct of commerce and other mercantile business, typically located in the central business district (CBD). Often consisting of a concentration of multi-level buildings, but also includes small commercial zones (i.e. spaza shops) within former black townships.
44	Urban / Built-up, (commercial, education, health, IT)	Non-residential, non-industrial sites or complexes associated with educational (i.e. schools, universities), business development centres such as industrial 'techno-parks', and / or social services (i.e. hospitals), often consisting of a concentration of multi-level buildings (Note : only mapped if clearly identifiable, otherwise included within '*commercial / mercantile*' or '*suburban*' categories.
45	Urban / Built-up, (industrial / transport : heavy)	Non-residential areas with major industrial (i.e. manufacture and/or processing of goods and products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards, train stations and airports (i.e. Johannesburg).
46	Urban / Built-up, (industrial / transport : light	Non-residential areas with major technology, manufacturing or transport related infrastructure. Examples would include light manufacturing units, warehouse dominated business development centres, and small airports (i.e. Lanseria). Also includes similar structures such as pig and battery hen breeding units.
47	Mines & Quarries (underground / subsurface mining)	Active or non-active underground or sub-surface based mining activities. Category includes all associated surface infrastructure etc
48	Mines & Quarries (surface-based mining)	Active or non-active surface-based mining activities. Includes both hardrock or sand quarry extraction sites, and opencast mining sites i.e. coal. Category includes all associated surface infrastructure.
49	Mines & Quarries (mine tailings, waste dumps)	Non-vegetated, exposed mining (and heavy industry) extraction or waste material

THE EFFECT OF LAND USE CHANGE AND FRAGMENTATION ON WATTLED CRANE *Bugeranus carunculatus Gmelin* NEST SITE OCCUPANCY IN KWAZULU-NATAL, SOUTH AFRICA.

BRENT M. COVERDALE[1*] and TREVOR HILL[2]

[1] Mondi Business Paper, P.O. Box 8 Melmoth, KwaZulu-Natal, South Africa

[2] Discipline of Geography, University of KwaZulu-Natal, Pietermaritzburg, South Africa

* Corresponding author: Tel: +2782 5609769; Fax: +2735 450 7911. E-mail: coverdale@telkomsa.net

For Submission to Agriculture, Ecosystems and Environment

Abstract

The decline in numbers of the critically endangered Wattled Crane *Bugeranus carunculatus* within South Africa has been ascribed to the loss of suitable habitat. The availability of an updated land cover database provided an opportunity to investigate the impact of land use change and fragmentation on nest site occupancy of the Wattled Crane for 55 active and 43 historical nesting sites, within the midlands of KwaZulu-Natal utilising digital satellite imagery. An average home range buffer centred around each nest site was used to determine the land cover composition and configuration within each home range of which a core breeding area (that area deemed crucial for successful breeding) was also investigated. The use of a Geographic Information System allowed for the determination of the Wattled Crane's preferred habitat types and to determine that the decline in numbers of the species has been as a result of the fragmentation of its preferred habitat type and not habitat loss alone as well as to other factors (power line collisions, poisonings etc). The presence of transformed land cover classes attests to the Wattled Crane's tolerance of some degree of transformation within its home range and to the fact that the species is more resilient than initially anticipated. Various numerical indices, such as patch size, perimeter-area ratio, nearest neighbour and interspersion and juxtaposition were calculated using FRAGSATS to quantify home range configuration. The fragmentation of the Wattled Crane's home range has resulted in nest site abandonment. The potential impact of management practices in and around nesting sites warrants further investigation because the impact could not be quantified through the analysis of the land cover database. The potential for historical nesting sites

to be re-populated exists. However, the small population of non-breeding individuals may currently not be able to populate these historical nesting sites and thus it is imperative that both current and historical nesting sites are protected from further alteration and human interference. The onus is thus on the private landowner to ensure the protection of the Wattled Crane and its nesting territories.

Keywords: Wattled Crane; Land cover; Habitat loss and fragmentation; Agriculture.

1. Introduction

The Earth's ever decreasing assemblage of and accelerated decline in biodiversity has received much attention over the last decade. Numerous organisations have published data highlighting that the extinction rates of plants and animals are a thousand times the natural rate and that the world is presently experiencing the phenomenon dubbed the 'sixth extinction' (Haney & Eiswerth, 1992; Tekelenburg, Prydatko, Alkemade, Schaub, Luhmann & Meijer, undated). However, as conservationists strive to conserve this ever dwindling biological diversity, they often compete with agriculture, forestry, recreation, urbanisation and industry for the same tracts of land (Morrison & Bothma 1998). Habitat transformation and its impacts as a result of these various land uses have been well documented (Winter & Morris 2001; Neke & Du Plessis 2004) and habitat transformation remains the principal cause of biodiversity loss throughout the world. The extent of such transformation within South Africa is particularly evident within the grassland biome. This area lends itself to agricultural transformation with its relatively flat terrain, deep, well drained soils and high rainfall (Coverdale & McCann 2005). The Wattled Crane, whose distribution within South Africa falls entirely within the grassland biome, presents an exemplary case for biodiversity conservation considering its conspicuous size and dependence on grasslands and wetlands (Meine & Archibald 1996). The Wattled Crane is a highly dependent wetland species, and as such is sensitive to deterioration in wetland quality. Such quality is affected by the surrounding land uses and thus the Wattled Crane represents a flagship species for not only wetland conservation but biodiversity conservation in general (Grenfell *et al.* 2005).

The conservation of the Wattled Crane is dependent on understanding the species habitat requirements (McCann *pers. comm.* 2005 Endangered Wildlife Trust – South African Crane Working Group). One such method to help understand such requirements is the utilisation of a land cover database. The representation and analysis of land cover and land use has been a major focus of Geographical Information Systems (GIS) applications since its inception (Bibby & Shepherd 1999). Land cover and land use are strongly related parameters yet remarkably different in their definitions. The term 'land cover' refers to the physical appearance of the earth's surface and consists of classifiable terrain objects whereas the term 'land use' refers to the various categories created according to the human use of the land and the economic benefits derived there from (Bibby & Shepherd 1999; Light & Jensen 2002; Konecny 2003). A change in land cover can have an impact on a range of potential land uses in any given area, whereas a change in land use can physically alter the land cover, in terms of either conversion or modification (Thomson 1999). The massive land use conversions of the past two centuries have changed many natural systems, predominantly forests and savannas to agriculture and pasture with the resultant effect on wildlife only realised after the event (Lavers & Haines-Young 1996), with the greatest land cover change being the intensification of land use through better management of production factors (Fresco 1994).

This large-scale transformation has increased the pressure on existing wetland and grassland habitats outside of formally protected areas within KwaZulu-Natal (Coverdale & McCann 2005). The dependence of the Wattled Crane on such areas combined with their large spatial requirements and the fact that their movement patterns take them outside of protected areas means that it is a near impossibility to try to conserve the Wattled Crane within formally protected areas. To support this contention, two nature reserves, specifically proclaimed to protect the Wattled Crane, namely the Umngeni Vlei Nature Reserve and Verlorenvlei Nature Reserve, have since being proclaimed recorded a decline in the number of Wattled Crane pairs. It is thus imperative that the areas within which Wattled Cranes currently occur and which are outside of protected areas are suitably conserved. The conservation of the Wattled Crane will ultimately benefit the natural habitats within which the species occurs thus resulting in the conservation of numerous other plant and animal species.

1.2 Wattled Crane Conservation

The Wattled Crane (*Bugeranus carunculatus* Gmelin) is the largest and rarest of the six crane species that occur within Africa. Three distinct subpopulations are recognised of which one occurs within South Africa. It is the most wetland dependent of all Africa's crane species and its low population numbers and 'Critically Endangered' conservation status (Barnes 2000) within South Africa is indicative of the poor state of South Africa's wetland habitats (Burke 1996). The degradation of these wetland habitats, primarily as a result of agricultural development, such as drainage and poor land use practices, has resulted in an estimated 50% loss or alteration of South Africa's wetland resources over the past 100 years (Begg 1990; Kotze *et al.* 1995). Ironically, it is ultimately mankind that benefits from the functions that wetlands provide.

Within South Africa's Wattled Crane population, two subpopulations are recognised, one in the northern parts of the eastern escarpment (Mpumalanga province) and the other in the south-central parts of KwaZulu-Natal. Figure 1 illustrates the location of the KwaZulu-Natal subpopulation. The KwaZulu-Natal subpopulation is the larger of the two comprising 65 breeding pairs and 67 non-breeding individuals, which constitutes 84.2 % of the entire South African population (McCann 2001). The subpopulation is restricted to the higher altitude areas of the midlands and southern Drakensberg mountain range, where it utilises for feeding and breeding requirements, high altitude, palustrine wetlands that are bounded by moist or dry, flat or undulating grasslands (McCann & Wilkins 1995; Morrison & Bothma 1998). It is the loss and fragmentation of this habitat, through the draining and damming of wetlands for agricultural purposes, the ploughing up of grassland for increased agricultural productivity and the expansion of exotic timber plantations that constitutes the greatest threat to the Wattled Crane. The KwaZulu-Natal population occurs within a landscape characterised by a mosaic of commercial agriculture and afforestation (McCann 2000; McCann & Benn *in press*). Accompanying the transformation of habitat are the impacts upon the ecosystems through increased disturbance, sedimentation of wetlands and poor management practices (fire, burning and grazing). The present consensus regarding these impacts is that they negatively impact on the breeding productivity and nest site occupancy of the Wattled Crane and that the marked decline in the breeding success of Wattled Cranes over the past two decades has been as a consequence of the change in land use and the accompanying management practices (Ronchini 1998; McCann 2002; McCann & Benn *in press*). Compounding the impact that habitat transformation has on breeding productivity, are numerous other threats that cranes presently face, namely; power line collisions, poisonings, fences and direct persecution and disturbance in and around breeding sites.

1.3 Habitat transformation

Landscapes can be characterised by both their composition and configuration. These two aspects of the landscape can independently, or in conjunction, have an impact on ecological process and species occurring in such landscapes (McGarigal & Marks 1994) and no more so, than with the Wattled Crane. The term 'landscape composition' refers to the presence and amount of those features associated with each patch type, in this case, land cover type, without being spatially explicit. Thus, landscape composition encompasses the variety and abundance of patch types but not the location or placement of such patches within the landscape mosaic. In contrast, the term 'landscape configuration' refers to the spatial configuration of patch types in relation to not only one another but also other features of interest. Thus, although a landscape may contain a considerable amount of grassland, such tracts may be small and widely dispersed in comparison to a single large tract of grassland, which may be of more benefit to a species.

Habitat transformation is not a unique threat to the Wattled Crane and it is the primary cause of biodiversity loss (Neke & Du Plessis 2004). Habitat transformation results in the reduction in local population sizes of both fauna and flora as well as in the decline in species richness. Habitat transformation consists of two distinct components, namely direct habitat loss and habitat fragmentation. Habitat loss is the more obvious of the two and results in the displacement of species that utilise such areas, with the possibility of the species becoming locally extinct. Habitat fragmentation is more subtle and, by definition, creates a greater number of patches that are smaller in size than the original contiguous tracts of habitat (Bender *et al.* 1998). This fragmentation tends to disrupt landscape connectivity, impeding dispersal of certain species, ultimately leading to more isolated populations and an enhancement of the extinction risk for any given species (Vander Hagen *et al.* 2000; With 2002). The decline of faunal and floral populations is often a consequence of both habitat loss and fragmentation which impacts simultaneously to compound the effect of decreased patch size, decreased connectivity between the remaining patches and increased distances between patches (Winter & Morris 2001; Fletcher 2005). Fragmentation can also reduce avian productivity through increased rates of nest predation, increased nest parasitism and reduced pairing success of males (Vander Hagen *et al.* 2000; Bollinger & Switzer 2002). The impact of habitat transformation on the Wattled Crane is particularly evident in terms of its flight patterns. Individuals are forced to move greater distances from the nest to forage, which can be particularly problematic during the breeding season. During such times, the birds are susceptible to the various threats such as new power lines, fences and disturbance (McCann *pers. comm.* 2005).

Not all transformation is, however, negative. The resultant mosaic of habitat as a consequence of fragmentation can result in increased 'edge effect', which in turn creates new niches that allow for the expansion of certain plant and animal communities and increases the alpha diversity within a specific area. Species that exhibit small area requirements or that are highly mobile and can easily move amongst small habitat patches thrive in such altered or fragmented habitats (Lacher *et al.* 1999). 'Weedy species' among plants are a case in point and can become dominant in a transformed and fragmented landscape. The agricultural landscapes that result from habitat transformation can also provide alternative food sources. Grain agriculture provides residue seed after harvesting which serves as a vital resource to many wildlife species. All three species of cranes in South Africa are known to utilise harvested maize (*Zea mays*) areas for foraging. The transformation of natural habitat in the Western Cape, South Africa, from a fynbos dominated system to an agriculturally dominated system has boosted Blue Crane (*Anthropoides paradiseus*) numbers in the region to the point that the area now contains more than half of the world's population (McCann *pers comm.* 2004). This is in stark contrast to the well documented decline of both the Blue and Wattled Crane in the eastern parts of South Africa as a result of habitat transformation (McCann & Wilkins 1995).

1.4 Bird-habitat relationships

One of the primary objectives of bird-habitat relationship studies is to be ble to identify the environmental variables that perceivably control the distribution and abundance of a bird species (Young & Hutto 2002). These distributions and abundances are highly dependant on plant communities and the distribution of bird territories is suggested to be influenced by the available resources within their habitats (McKernan & Hartvigsen 2001). The physical structure of the habitat within which any particular bird species may occur has long been considered to provide cues for habitat selection. The differing vegetation layers provide material for nesting, protection from predators and foraging opportunities. The species composition of the vegetation affects resource availability and foliage distribution which may also be important for certain bird species. This in turn influences foraging opportunities and potential nest site selection (Young & Hutto 1998). The structure of the vegetation may also affect the ease of movement for foraging birds both physically and behaviourally and may influence foraging efficiency through its effects upon the detectability and accessibility of food items (Hill *et al.* 2004). The vegetation structure is thus a key component in determining habitat quality. Habitat quality thus impacts upon reproductive success, nest density and survival rates of avian species (Betts *et al.* 2005).

The spatial arrangement of habitats within the landscape potentially has a strong influence on the abundance, distribution and dynamics of avian populations. Most species exhibit a well-defined habitat preference (McKernan & Hartvigsen 2001) and thus the relative area of habitat occupied by the Wattled Crane and its distribution may be important when explaining patterns of population dynamics. Bird-habitat relationships help to identify habitat features that are of importance to a particular bird species which in turn can assist managers to determine which vegetative features to manage on a regional scale (Heath & Ballard 2003).

This paper investigates to what extent land cover and land use have influenced nest site occupancy for Wattled Cranes within KwaZulu-Natal. Land transformation has been cited as the principal cause for nest site abandonment and the decline in numbers of the species within KwaZulu-Natal (McCann 2000) and this paper investigates the validity of such assertions. Particular emphasis was placed on home range composition and configuration within an average home range size, centred on the nest site. A core breeding area was also investigated. The size of each home range and core breeding area were derived from McCann and Benn (*in press*) for comparative purposes. The use of an average home range allowed for the investigation of the land cover surrounding historical sites and whether or not such sites are still suitable for nesting purposes.

2. Methods

2.1 Area description

The Wattled Crane pairs utilised in this study were located in the 'midlands belt' of the province of KwaZulu-Natal, South Africa, from Greytown (29^0 03'S; 30^0 35'E) in the East through Mooi River (29^0 12'S; 29^0 43'E) and southwards towards Underberg (29^0 47'S; 29^0 29'E), including Kamberg and Nottingham Road. The area includes six nature reserves, the Stillerust section of the Kamberg Nature Reserve, the Umngeni Vlei Nature Reserve, the Highmoor Nature Reserve, the Midmar Nature Reserve, the Himeville Nature Reserve and the Coleford Nature Reserve. Figure 1 illustrates the location of the study area.

INSERT: Figure 1

The landscape of the KwaZulu-Natal midlands is dominated by an array of agricultural and commercial afforestation transformations. Agricultural operations include dairies, piggeries, beef production, horse studs and sheep rearing, whilst in many areas there is cultivation of maize, potatoes and vegetables interspersed. Irrigated lands that are utilised either for fodder production or year-round dairy feed are common, whilst *Pinus* and *Eucalyptus spp* are the plantation species of choice (McCann & Benn *in press*). The extent of this transformation and habitat modification is greater than in any other country or province within southern Africa and it is estimated that 25% of the province is currently transformed (Scott-Shaw 1999).

2.2 Techniques

Ninety-eight Wattled Crane pairs were selected for this study. The data has been collected over the past 10 years through various members of staff of the KwaZulu-Natal Crane Foundation (KZNCF), the Endangered Wildlife Trust's South African Crane Working Group (SACWG) and Ezemvelo KwaZulu-Natal Wildlife. Included were 55 active breeding pairs, where the term 'active' indicates some attempt at breeding over the preceding five-year period and 43 historical breeding sites. 'Historical sites' are defined as those where no birds have been recorded for a period longer than five years up until the period in which the land cover data was compiled i.e. 2000. This resulted in 79% of all active and 78% of all historical nest sites being analysed for this study. There are currently 70 active nest sites situated in KwaZulu-Natal, located predominantly within the 'midlands belt' of the province.

McCann and Benn (*in press*) have calculated the home range of Wattled Cranes within KwaZulu-Natal to be 16.26km^2 (sd = 24.29km^2). Thus, buffer zones around each of the nest sites were created within the GIS to represent the estimated home range, where the nest site was taken to represent the central point of each home range. The land use/cover classification utilised during this study was in accordance with the South African classification system, as defined by Thompson *et al.* (2001) [Appendix 1] and the data were obtained from the National Land Cover (NLC) 2000 project. These data are based upon 2000-2001 LANDSAT Thematic Mapper (TM) satellite images. 49 different land cover classes are described and the data are designed for 1: 50 000 mapping applications (minimum mapping unit = 1ha).

The NLC 2000 dataset and individual pair's home ranges were combined utilising overlay techniques available in a GIS. As a result of the similarity of certain land cover types within the database, it was decided to merge those variables that were similar to each other, so as to avoid multicollinearity during the analysis of the data. The knowledge of the biologically important variables will help to make more informed decisions pertaining to the choice of independent variables to be modelled (Young & Hutto 2002). The dependence of the Wattled Crane upon both grasslands and wetlands for its survival (Burke 1996) and its ability to tolerate some form of habitat transformation (McCann 2000) aided in the formation of four habitat variables. These are:

Optimal habitat, deemed as the habitat most preferred by the Wattled Crane (Burke 1996), in which the Unimproved (natural) Grassland and Wetland land cover types were merged.

Sub-optimal habitat included natural habitat types that may have some form of modification, that are utilisable throughout the year, and yet may not provide all the necessary dietary requirements. These include, Thicket, Bushland, Bush clumps, High Fynbos, Improved Grasslands, Degraded Unimproved (natural) Grassland and Degraded Thicket, Bushland, Bush clumps, High Fynbos.

Marginal habitat included modified land cover types that are not available for foraging throughout the year. These include, Cultivated, temporary, commercial, irrigated crops, Cultivated, temporary, commercial, dryland crops and Cultivated, temporary, subsistence, dryland crops.

The final habitat variable, Excluded habitat, included the land cover types deemed not suitable for the Wattled Crane, either as a result of total habitat transformation or the associated disturbance. This group included all Plantation Forestry, Urban development and waterbodies.

The integration of the various land cover types within the GIS facilitated the determination of the habitat and land use composition for each individual pair and the mean patch size for the various land use types within each home range. Within each individual home range, the area (hectares) and nearest neighbour distance (metres) for each fragment was calculated. A variety of metrics, including area, patch density, size and variability, edge, shape, nearest neighbour, diversity, contagion and interspersion, were calculated using FRAGSTATS 3.3 (McGarigal 1995) at the scale of patch type and landscape. The calculation of these metrics enabled one to determine the amount of fragmentation of each home range.

The paucity of breeding data i.e. hatching and fledgling success for Wattled Crane pairs in KwaZulu-Natal, meant that it was not possible to analyse breeding data and subsequent breeding productivity as part of this paper. Therefore a concerted effort should be made by the conservation bodies responsible for crane conservation in KwaZulu-Natal to obtain more breeding data in order that a suitable analysis can be carried out. Such an analysis would be beneficial to the management recommendations currently advocated for active nesting sites.

The data obtained through the GIS investigation were analysed using a logistical regression model (Quinn & Keough 2002), which was deemed more appropriate as the data were not of a normal distribution and sites were either active or historical i.e. 0 or 1. The use of this method may however mask the more subtle differences in habitat quality. The scientifically accepted 95% confidence interval was applied and although limited significant differences existed in the various analyses performed between active and historical nesting sites, the nature of the data set being interrogated must be borne in mind. A number of external factors present themselves when analysing land cover, i.e. labour and livestock movement and thus, the effect of land cover composition within Wattled Crane home ranges cannot be ruled out altogether.

3. Results

The results are categorised according to the three separate analyses undertaken. The first investigates the composition of the home range utilising the original land cover categories, the second investigates the composition utilising the new set of habitat variables whilst the third investigates the configuration of the home ranges. An attempt has been made to determine whether or not any differences exist between active and historical Wattled Crane home ranges, utilising the new set of habitat variables. A summary of P values calculated are listed in Appendix 3. The values listed in the various tables are mean scores, unless otherwise stated. The land cover composition utilising the new set of habitat variables of the core breeding area was also analysed.

3.1 Home range composition results

The composition of both active and historical Wattled Crane nest site home ranges according to the various land cover classes are presented as Table 1 and illustrated (figure 2). The percentage of the landscape that each class occupies throughout all the home ranges, as well as the difference in area is included in Table 1. The results expressed in Table 1 represent the percentages recorded across all of the home ranges analysed, not only of those home ranges within which a particular land cover class was recorded.

The dominance of Unimproved (natural) Grassland is evident in both active and historical home ranges with 51% of all active home ranges consisting of Unimproved (natural) Grassland in comparison to the 48% of historical home ranges. Despite this land cover class occurring in all the home ranges analysed, there is no significant difference (P=0.215) between the amount of grassland present in either the active or historical home ranges and thus the loss of grassland cannot be attributed to the abandonment of nesting sites. The large percentage of grassland cover reflects the Wattled Crane's dependence upon natural grassland for its survival.

Cultivated, temporary, commercial, irrigated crops, described as areas of land that are ploughed and or prepared for commercial markets and are subject to intensive management such as irrigation and are harvested at the end of the growing season, account for the second most dominant land use type, when recorded within the home range, in both active and historical sites, amounting to 213.79ha (9.4%) for active sites and 265.97ha (11.1%) for historical sites. The increase in this type of land use is to be accepted considering the amount of transformation that has taken place within the Wattled Crane's distribution in KwaZulu-Natal (McCann 2000).

INSERT: Figure 2

Thicket, Bushland, Bush clumps, High Fynbos, described as communities typically composed of tall, woody, self-supporting, single- or multi-stemmed plants with no clear, definable structure, is prevalent in both active and historical ranges, amounting to 203.87ha (12.14%) and 198.49ha (12.3%) of the home range (Table 1) respectively.

Wetlands, upon which the Wattled Crane is dependent for breeding, comprise 7.1% of all active home ranges and 6.5% of all historical home ranges. This difference in composition is, however, not deemed to be sufficiently significant to cause nest abandonment (P=0.227). As a result of the reliance of the Wattled Crane on wetlands for breeding (Burke 1996), a loss of such areas should ultimately cause the demise of the species. The lack of any significant difference in the composition of the wetland cover class between active and historical sites does not rule out that other factors directly related to the wetland i.e. burning and grazing, could ultimately have a negative impact on the species.

Waterbodies comprise a small proportion of both active (1.8%) and historical (2.3%) home range sites. Wattled Cranes have been known to utilise the headwaters of dams for breeding (Filmer & Holtshausen 1992) and the analyses of sightings data for KwaZulu-Natal indicate that 14% of Wattled Crane pairs were located in the headwaters of dams. It is likely that these pairs utilise this area for foraging and the area would not be suitable for breeding purposes as a result of the alteration of vegetation structure. The natural, heterogeneous structure of a wetland's vegetation creates patchiness in the crane's nesting habitat. This patchiness affords protection for unfledged juveniles whilst simultaneously allowing for foraging areas (Morrison & Bothma 1998). The damming of wetlands, on the other hand, alters the nature of the wetland because its size is diminished. This diminished size, limits the availability of suitable habitat for foraging and protection from predators.

Table1: Mean area (ha) for both active and historical nesting sites (land cover classification)

Description of land cover (class)	Mean class area (ha)	Percentage of landscape	Mean class area (ha)	Percentage of landscape	% Difference
	Active		Historical		
Unimproved (natural) Grassland	822.65	50.84	773.81	47.84	3.01
Thicket, Bushland, Bush Clumps, High Fynbos	196.35	12.14	198.43	12.27	-0.13
Cultivated, temporary, commercial, irrigated	151.58	9.37	179.38	11.09	-1.72
Cultivated, temporary, commercial, dryland	55.06	3.40	48.50	3.00	0.40
Waterbodies	28.64	1.77	36.49	2.26	-0.48
Wetlands	115.35	7.13	105.82	6.54	0.59
Forest Plantations	141.20	8.73	194.58	12.02	-3.30
Degraded Unimproved (natural) Grassland	32.78	1.93	20.93	1.29	0.64
Degraded Thicket, Bushland, etc	7.85	0.48	1.55	0.10	0.39
Forest (indigenous)	29.29	1.81	22.34	1.38	0.43
Improved Grassland	31.08	1.92	26.85	1.66	0.26
Cultivated, temporary, subsistence, dryland	6.59	0.41	3.25	0.20	0.21
Bare Rock and Soil (natural)	0.003	0.00	0.06	0.00	0.00
Urban / Built up (residential formal suburb)	0.94	0.06	3.96	0.24	-0.19
Urban / Built up (residential)	0.00	0.00	0.96	0.06	-0.06
Urban / Built up (small holdings grassland)	0.07	0.01	0.00	0.00	0.00
Urban / Built up (rural cluster)	0.00	0.00	0.76	0.05	-0.05

From the analysis of the home range composition in GIS, all the different Forestry Plantation land cover types were merged into one and termed Forest Plantations. It was assumed that no particular type of Forestry species i.e *Pinus* or *Euclyptus* species would impact differently upon the Wattled Crane. Commercial forestry, in general, has received wide criticism as a result of its perceived impact upon grassland transformation and negative impact upon biodiversity (Allan *et al.* 1997). The forestry component recorded across both active and historical home range sites equates to 8.7% and 12.0% respectively.

Improved Grasslands, defined as either indigenous or exotic grass species grown under man-made conditions, occur within a limited percentage of home range sites (active=1.9% and historical=1.7%). Cultivated, temporary, commercial, dryland crops, receive no irrigation and are not as widely distributed as the irrigated equivalents, amount to 3.40% of active sites and 3.0% of historical sites.

3.2 Wattled Crane Habitat variables

The composition of both active and historical Wattled Crane nest site home ranges according to the grouped habitat classes are presented as figure 3 and figure 4 respectively.

The dominance of optimal habitat is evident in both active and historical home ranges, prevalent within 58.0% of all active home ranges and 54.4% of all historical home ranges. The data represented in figure 4 are different from those expressed in Appendix 2 in that they represent the percentages recorded across all of the home ranges analysed, whilst the results expressed in Appendix 2 are only of those home ranges within which a particular habitat class was recorded. Certain habiat classes do not occur in all the home ranges analysed, yet within the home ranges that they do, they may be more or less dominant and thus occupy a greater or smaller percentage of the landscape than when the results are calculated across all the home ranges. Thus, it is important to describe and interpret both percentages. The difference of this land cover classification can however not attest to nest site abandonment (P=0.833). The prevalence of such a large percentage of optimal foraging habitat within both active and historical home ranges supports the dependence of the species reliance upon both wetlands and grasslands for its survival (Allan 2005).

INSERT: Figure 3

INSERT: Figure 4

Sub-optimal habitat accounts for 16.5% of active home ranges and 15.3% of historical home ranges, however the difference is not deemed significant (P=0.833). The increase in marginal, (14.3% as to 13.2%), and excluded habitat (16.0% as to 12.4%) within historical home ranges is also not deemed significant (P=0.833).

3.3 Home range configuration

Fragstats 3.3 (McGarigal 1995) allows the user to investigate the configuration of landscapes. However, one needs to take cognizance of the fact that the conversion of the initial vector land cover data to a raster format has an impact on the pixel size of the data, hence the slight variation in the class area sizes in Appendix 2 in comparison to those illustrated in figure 4. The metric values calculated using Fragstats are presented in Appendix 2. As part of the home range analysis, the distances from the nest to the various habitat classes were also analysed. These distances, in metres, are summarised in Table 2 and illustrated in figure 5. These values, calculated using the Nearest Neighbour function, are from the position of the nest to the edge of the various habitat classes. The mode for each habitat class is included as it was assumed that outlying patches would increase the size of the mean distance and thus would not be a true reflection of the results. The large standard deviation values attest to the assumption being correct.

INSERT: Figure 5

The distribution of optimal habitat is more uniformly distributed across the home range for both active and historical sites. This is indicated by the smaller variation in mean nearest neighbour (MNN) distances (Appendix 2) and the low value for nearest neighbour standard deviation NNSD (Appendix 2) in comparison to other habitat classes. It is the least fragmented of the habitat classes, indicated by the highest mean proximity index (MPI), (Appendix 2). Historical sites have a greater mean number of optimal habitat patches (n=19) in comparison to active sites (n=17), per home range, with the total number of patches per home range being deemed to be significant

(P=0.026). The size of such patches is greater for active sites (mean=31.46ha) than that of historic sites (27.78ha), however not deemed to be significant (P=0.746). The perimeter-area ratio, defined as the defined as the ratio of perimeter of the patch to its area, is significantly larger for historical sites (P=0.045) which would attest to the fragmentation of both grassland and wetland habitats (Appendix 4). The patch size of each individual recorded habitat class patch varies greatly, resulting in a large value for patch size coefficient of variation (PSCV), (Appendix 2). Optimal habitat patches are moderately well interspersed and dispersed throughout the home ranges: the Interspersion and Juxtaposition indices are both greater than 50%. No significant difference exists for mean nearest neighbour distance. The distance from the nest site (Table 2) is also not significant (*P*=0.093) between active and historical nesting sites.

Sub-optimal habitat is not well interspersed and dispersed throughout the home ranges: the Interspersion and Juxtaposition indices (IJI=48% for active and 43% for historical sites) are less than 50%. No significant differences exist for patch size, number of patches and mean nearest neighbour distance for this habitat class types.

Marginal habitat is moderately interspersed and dispersed throughout both home ranges (IJI=53% and 51% for historic and active home ranges respectively). No significant differences exist for patch size, number of patches and mean nearest neighbour distance for this habitat class type. The distance from the nest site is also not significant (*P*=0.349) between active and historical nesting sites.

The excluded habitat class is not well dispersed through active home ranges the Interspersion and Juxtaposition indices equal to 33.8%. However the IJI equals 68% for historical sites, thus indicating that this habitat class is uniformly spread throughout historical home ranges. The distance from the nest to the excluded habitat differs significantly (P=0.014) between active and historical home ranges.

Finally, all habitat class types are fairly evenly interspersed and dispersed across the landscape as the contagion and interspersion (CON = 68.96 for active and 68.93 for historical sites) and interspersion and juxtaposition indices (IJI = 57.33 for active and 57.97 for historical sites) are greater than 50% which indicates considerable landscape heterogeneity for both active and historical home ranges.

Table 2: Distance (in metres) from nest to habitat class

Status of nest	Description of land cover	Distance to edge (m)				
		Mean	Mode	Maximum	Minimum	Standard Deviation
Historical	Optimal forage habitat	1 523.6	2.69	2 273.45	1.13	599.73
	Sub-optimal forage habitat	1 495.6	36.99	2 274.67	1.13	569.69
	Marginal forage habitat	1 447.2	17.08	2 273.68	17.08	606.10
	Excluded forage habitat	1 494.9	20.59	2 272.18	19.87	574.78
Active	Optimal forage habitat	1 488.9	0.96	3 351.59	0.96	624.82
	Sub-optimal forage habitat	1 513.5	2 251.64	3 437.43	1.24	580.51
	Marginal forage habitat	1 476.1	19.61	3 380.28	19.02	606.85
	Excluded forage habitat	1 557.6	1 504.65	3 325.92	6.49	544.44

3.4 Core breeding area

McCann and Benn (*in press*) calculated the core breeding area to constitute 2.3% of the home range and is defined as the area that is essential for successful reproduction. The composition of both active and historical Wattled Crane nest site core breeding areas according to the various habitat classes are presented as Table 3 and illustrated (Figure 6 and 7 respectively). The percentage of the core breeding area that each class occupies, as well as the difference in area is included in Table 3.

INSERT: Figure 6

INSERT: Figure 7

The core breeding areas for both active and historical sites consist predominantly of optimal habitat (Unimproved (natural) Grassland and Wetland). This would concur with the literature and the reliance by the cranes on these two habitat types for their survival (Burke 1996). Despite the presence of other habitat cover types within the core breeding area, nest site abandonment cannot be ascribed to these transformed habitat types.

Table 3: Habitat class composition within the core breeding areas

Description of land cover (class)	Total class area (ha)	Percentage of landscape	Total class area (ha)	Percentage of landscape	% Difference
	Active		Historical		
Optimal forage habitat	1 694.87	73	986.91	56	17
Sub-optimal forage habitat	340.52	15	189.53	10	-5.0
Marginal forage habitat	154.95	7	262.11	14	-7.0
Excluded forage habitat	124.48	5	369.37	20	-15

4. Discussion

Accepted opinion has highlighted that the loss of habitat, both breeding and feeding habitat, constitutes the greatest threat to the Wattled Crane (McCann 2000). The loss of wetlands through damming or modification through draining for agricultural purposes and the degradation or loss of the surrounding grassland habitat is highlighted as the single greatest contributing factor to the decline in numbers of Wattled Cranes within South Africa (McCann 2000). Contrary to this opinion, the results indicate that it is not necessarily the direct loss of habitat, as there is no significant difference between the total composition of the various habitat of active and historical nesting sites, even when similar habitat types are classified together, but rather the resultant configuration of the remaining habitat that has contributed to or exacerbated the abandonment of nesting sites.

4.1 Habitat transformation

The fragmentation of habitat increases the amount of edge relative to the habitat area and the significant difference that exists between active and historical sites in terms of the perimeter-area ratio and the number of patches, supports the theory that the increase in edge effect can be disadvantageous to certain species (Winter & Morris 2001). The increase in edge can serve as ecological traps for breeding birds by concentrating nests within small areas with the resultant risk of increases in predation and disturbance (Lacher *et al.* 1999). The wetlands identified in this study, on which the Wattled Crane is dependent for breeding, are not evenly distributed across the landscape and although they are to a certain extent geographically distinct units, the potential for connectivity between wetlands could have been disrupted by the transformation of the surrounding habitat and by degradation of the wetland itself. Grenfell *et al.* (2005) conclude that the transformation of natural grassland as a result of afforestation surrounding a wetland has a negative impact on the system's floristic component. This alteration, causing a reduction in the permanent to semi-permanent wetland vegetation, would not be detected for a particular area during the type of analysis utilised for this study. Such alterations may, however, be responsible for the abandonment of nesting sites, as a result of the alteration of vegetation structure. Bentos (2002) identified that the change in hydrology in the Zambezi delta floodplain resulted in a decrease in *Eleocharis* spp, a sedge which formed a main part of the Wattled Cranes diet. No such detailed investigation into the Wattled Cranes dietary requirements in South Africa has been undertaken and thus it can only be suggested that such alterations to hydrological functioning of wetlands may be a limiting factor to the Wattled Crane's nest selection. To ascertain the effect of habitat fragmentation it would be necessary to investigate the change in land cover over time so as to compare landscape metrics. Godron and Forman (1983) predict that within an increasingly transformed and fragmented landscape, the number of patches will increase, patches will become smaller and the shape of patches will become more circular and regular. The transformation of the Wattled Crane's optimal habitat within historical home ranges thus supports this notion as they contain significantly more patches than active nesting sites and that the wetland patches are noticeably smaller. The delayed response of avian populations to agricultural intensification implies that the effect of the change of habitat quality may become apparent only several years later (Manel *et al.* 2000). Thus, the cause of the abandonment of Wattled Crane nesting sites could have been initiated long before the birds were no longer active in the area. Therefore, land use practices and their spatial alignment can be used firstly as indicators of habitat degradation and secondly to potentially explain the decline of species' populations.

Bender *et al.* (1998) predict that as fragmentation increases within the landscape, non-migratory species face the risk of a decline in numbers. As the Wattled Crane is deemed to be a non-migratory species in South Africa, continued fragmentation could potentially cause the further decline in numbers of the species. However, the heterogeneous nature of the landscape within which the Wattled Crane exists implies that the species can tolerate some degree of transformation within its home range. It is not possible however, from the results of this paper, to determine to what extent it can of transformation it can tolerate as there is no significant difference between the composition of active and historical Wattled Crane home ranges. The results do indicate that the expansion of predominantly plantation forestry in and around the nesting site has resulted in nest site abandonment. Certain of the pairs observed in this study are able to tolerate more transformation than others. One pair in particular, nested between two mature plantation compartments and once the chick has hatched the family move to an adjacent wetland area with improved visibility. The potential food source that transformation provides probably benefits the Wattled Crane during the winter months, especially when food may be limited. Sightings recorded during the winter months within transformed habitat types account for 22% of all sightings of non-breeding birds. Such records confirm the Wattled Crane's utilisation of transformed habitat types. The uniformity of spread of excluded areas attests to the systematic transformation that has taken place within the historical nesting area. The significant difference in the distance of the nest from excluded areas can account for nest site abandonment in that the nature of Forestry would limit visibility and exclude afforested areas as foraging areas. Thus, although Wattled Cranes can tolerate a certain degree of transformation, it is imperative that no afforestation takes place in the immediate vicinity of the nesting site.

The fragmentation of wetlands and grasslands, as a result of human activities, has resulted in the decline of numerous bird species and is thus not limited to the Wattled Crane (Newton 1998; Ratcliffe & Crowe 2001). This creation of fragmented natural habitat patches has negatively influenced the survival and breeding productivity of bird populations (Malan & Benn 1999) within KwaZulu-Natal. The configuration of the remaining available habitat within the landscape plays a crucial role in the distribution of the Wattled Crane and as agricultural development is inevitable, further development within the Wattled Cranes distribution, needs careful planning. Non-migratory species, such as the Wattled Crane suffer greater population declines through habitat fragmentation, in comparison to migratory species and is thus imperative that linkages and corridors, or so-called 'stepping stones' (McGarigal & Marks 1994) are maintained between suitable breeding and foraging areas. The direct loss of habitat within the landscape and subsequent composition of available habitat are not the only factors influencing the distribution and population numbers of the Wattled Crane.

4.2 Habitat Management

The management strategies that occur within the home ranges of Wattled Cranes vary considerably from formally protected Nature Reserves to communal grazing lands. However, the dominant management structure is commercial agriculture. The consequence is that the primary motive in management within the landscape is profit. Therefore, limited consideration is given to management practices beneficial to the Wattled Crane. Intensification of commercial agriculture during the past decade has contributed to increased production yields through technological advances in machinery, fertilizer and pesticides yet intensification has simultaneously had a negative impact on biological diversity (Briggs & Courtney 1989; Piper 1999). Over the last 40 to 50 years the agricultural industry's methods and systems have changed from being relatively favourable to wildlife and biodiversity to a highly specialised and technical business, whose main function contradicts the maintenance of diversity sought by conservation (O'Connor & Shrubb 1986). The increase in the presence of agricultural land cover types within historical nesting areas, although not significantly different when compared to active nesting sites attests to the increase in agricultural productivity. Considering that an estimated 95% of all crane populations occur on privately owned land, this increase in agricultural production may ultimately have a immense impact on the species if it continues unabated.

Accompanying such agricultural intensification is an increased management input and the associated disturbances through the increased presence of farm labour, machinery and daily agricultural activities such as the application of pesticides (Tivy 1990). The impact of disturbance on Wattled Cranes has been well documented (Abrey 1990; Burke 1996) and the species responds to disturbance from humans in the same manner they would respond to the risk of predation: they completely avoid areas of high risk or utilise them for short periods of time (Gill *et al.* 1996). The disturbances associated with an increase in agriculture may be subtle in that the alteration of the land cover is not significant yet the activities may be sufficiently significant to cause the abandonment of nesting sites.

The alteration of the landscape through agricultural management i.e. burning of the wetland and surrounding vegetation could increase nest predation. The protection that a wetland affords to cranes in deterring predators has been noted by Morrison and Bothma (1998) for the Eurasian Crane (*Grus grus*) and the Brolga Crane (*G. runicundus*). Likewise, in South Africa, wetlands protect the Wattled Crane from predators. This shift in balance caused by altered landscapes favours predation and may result in the original pairs abandoning their nesting sites and vacating the area completely. The mismanagement of habitat through indiscriminate burning practices, resulting in the decline of species, has been well documented for a number of bird species across the globe (Gilpin *et al.* 1992; Díaz *et al.* 1996; Pienkowski *et al.* 1996) and is thus not unique to the Wattled Crane.

4.3 Breeding requirements

McCann and Benn (*in press*) calculate the core breeding area of the Wattled Crane to constitute 2.3% of the entire home range and define the core breeding area as the area that is essential for the successful reproduction of the species. The presence of transformed habitat types within the core breeding area attests to the species tolerance to some degree of transformation. However, it is not possible to attribute the abandonment of nesting sites to transformation within the core breeding area. The ability of the species to nest in the shallows of a dam, once a wetland has been flooded, further supports the notion that habitat loss alone is not responsible for nest site abandonment.

The availability of a limited resource within the landscape can account for the variation in home range size amongst various pairs of the same species. This variation can account for the year-to-year differences in survival and reproductive successes of neighbouring pairs or groups resulting in certain groups or pairs being classified as more productive than others (Ligon & Stacey 1996). Thus, within a population, certain groups or pairs may be deemed to be 'sources' and others as 'sinks'. Although insufficient breeding data are available for the Wattled Crane in terms of hatching and fledgling success, could the lack of a critical resource, defined as that resource which is crucial for survival and reproduction, within historical home ranges have caused the abandonment of these nesting sites? The answer to this question would involve a detailed study of the ecological and feeding requirements of the Wattled Crane. Being able to determine which sites could be deemed to be more productive than others would benefit the various crane conservation bodies in concentrating their efforts and resources on worthwhile projects, so as to ensure that less productive sites are suitably managed to ensure their continued contribution to the recruitment population.

The significant difference between active and historical nesting sites in the distance from the nest to the nearest wetland could possibly account for the critical resource that is required for survival and reproduction, considering the wetland dependent nature of the Wattled Crane. Considering that one would expect to find the nest within the wetland and so within the core breeding area, does this significant difference in distance between the nest and wetland (for active and historical nests) imply that the wetlands within which the Wattled Crane used to breed no longer exist and that those wetlands on the periphery account for the lack of significant difference in home range composition? This seems unlikely considering the 'ground truthing' that was done as a part of this research to investigate the presence of a wetland in which historic pairs were recorded as having bred. The vulnerability of the chick during the pre-fledgling stage ensures that both parents and the chick do not depart from the safety of the wetland for long periods of time. Limited resources within the wetland may cause the birds to seek out other wetland areas with the distances between such areas being of critical importance.

4.4 Suitability of the technique

The lack of any significant results pertaining to home range composition in this paper could be attributed to the data utilised. The suitability of the land cover data to investigate differences in land cover and their potential impact on nest site selection can be questioned considering the scale at which the NLC 2000 data are comprised and the quality thereof. At the time this study was conducted, the data that were made available were still in the process of being 'cleaned' and thus discrepancies could exist. A large amount of ground verification of the data took place and because only small discrepancies existed within the data, these were deemed to be insignificant. Where possible, discrepancies were corrected prior to the final analyses. The scale of the data could however remain a potential limiting factor, especially considering the findings of Baker *et al.* (1995), in their investigation into the nesting habitat of the Greater Sandhill Crane (*Grus Canadensis tabida*), who conclude that there is no habitat selection beyond 200m from the nest. Choosing the wrong geographical scale can lead to the wrong conclusions or the inability to draw conclusions. If Wattled Cranes selected nesting sites according to the immediate vegetation and the scale of the land cover data is unable to differentiate differences at such a fine scale, then the results would prove inconclusive. This finer resolution within a single habitat cover type are the features that are required to be known if the Wattled Crane is to be managed successfully (Young & Hutto 2002). Another concern pertaining to geographical scale, is the fixed extent of the study area relative to the distribution of the Wattled Crane. Most historical sites occur within the current distribution of active sites which allows for the overlapping of buffers and thus the likelihood of detecting differences is diminished.

The utilisation of land cover data to assess differences in habitat composition is not new, yet may not be suitable for species with specific habitat requirements such as the Wattled Crane (Burke 1996) or for studies limited to specific home range sizes. The land cover data would however prove useful, if a comparison could be made to historical land cover data. It is envisaged that the National Land cover database is to be updated every five years, which would thus allow for comparative longitudinal studies over time.

4.5 Resilience of the species

Could the Wattled Crane be more resilient than initially anticipated, despite the susceptibility of the Wattled Crane to habitat transformation (Burke 1996) being cited as the primary reason for the decline in numbers of the species? The presence of transformed habitat types within both its home range and core breeding area could attest to the resilience of the species. Obviously if a wetland is dammed it is likely that a pair would abandon a nesting site. However, the transformation of the surrounding grassland may not immediately cause nest site abandonment and there may be a lag time for the impact of the transformation to become apparent. The domino effect of habitat change and the accompanying management practices may be the cause of nest site abandonment.

5. Conclusion and recommendations

The 'Critically Endangered' status (Barnes 2000) of the Wattled Crane in South Africa has led to numerous conservation efforts highlighting the plight of this wetland dependent species. Central to many of these efforts has been the notion that the loss of habitat has directly led to the decline in numbers of the species and the abandonment of breeding sites (McCann *pers. comm.* 2005). The purpose of this paper was to investigate the validity of such a notion, utilising the most recent land cover data. The lack of any significant differences for the composition of active and historical home ranges nullifies this notion. However, the fragmentation of grasslands and wetlands and the location of afforestation to nesting sites in conjunction with other factors, it must be concluded have contributed to the decline in numbers of the Wattled Crane. The results should not, however, detract from the severe impact of habitat transformation that the Wattled Crane, and biodiversity in general, currently faces.

The initial occupation of breeding territories by Wattled Cranes could have occurred when the vegetation, climate patterns, habitat management and disturbance levels were different from what they are today. The resultant change over time may have had an impact on certain pairs to the point where they were driven from their territories, whilst others may have become accustomed to these changes. The death of certain pairs as a result of other threats i.e. power line collisions, poisonings etc, may have left certain suitable nesting sites vacant and the small population of non-breeding birds is currently not able to populate such sites. It is thus imperative that both existing and historical nesting sites are safeguarded from further alteration (habitat transformation) or interference (management) if the Wattled Crane is to survive. The onus is on the private landowner to ensure such survival. However, support from government is needed so that environmentally favourable management practices can be rewarded. The various conservation bodies need to determine to what extent the various management practices that occur in and around nesting sites have an impact on both the breeding productivity and nest site selection of the Wattled Crane. However, in order for this to happen a more detailed analysis of these practices needs to be undertaken, yet a severe limiting factor is the inadequate recording of data by the landowners who are responsible for such management. Whether or not suitable data could be acquired from landowners remains to be seen.

The impact of habitat transformation and fragmentation on biodiversity, which has impacted upon the nest site selection of the Wattled Crane, is well documented and the use of a GIS to determine such impacts will aid wildlife managers in allocating the appropriate resources to address the consequences of transformation on biodiversity. The conservation of the Wattled Crane will not only address problems of the species itself and its individual habitat requirements but also the maintenance of biodiversity within the grasslands and wetlands within which the Wattled Crane occurs. This will aid South African conservationists in meeting their international obligations to conserve biodiversity.

Acknowledgements

We would like to thank the Council for Scientific and Industrial Research (CSIR) for affording us the opportunity to utilise the NLC 2000 data prior to the completion of the project. We are also indebted to the staff of both the KwaZulu-Natal Crane

Foundation and Ezemvelo KZN Wildlife who, through the years, have helped to monitor the various Wattled Crane pairs and in so doing, to collect valuable breeding data.

References

Abrey, A.N., 1992. The Wattled Crane: Hatching and Raising in Captivity. In: Porter, D.J., Craven, H.S., Johnson, D.N., Porter, M.J., (eds.). *Proceedings of the First South African Crane Conference*. Durban: The Southern African Crane Foundation.

Allan, D.G., 2005. Wattled Crane. In: Hockey, P.A.R., Dean, W.R.J., Ryan, P.G., (eds). Roberts – Birds of Southern Africa, VII[th] Ed. Cape Town: The Trustees of the John Voelcker Bird Book Fund.

Allan, D.G., Harrison, J.A., Nacarro, R.A., van Wilgen, B.W., Thompson, M.W., 1997. The Impact of Commercial Afforestation on Bird Populations in Mpumalanga Province, South Africa – Insights form Bird atlas data. *Biological Conservation* (79): 173-185.

Baker, B.W., Cade, B.S., Mangus, W.L., Mcmillen, J.L., 1995. Spatial Analysis of Sandhill Crane nesting habitat. *Journal of Wildlife Management* 59 (4): 752-758.

Barnes, K.N., 2000. *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland.* Johannesburg: Birdlife South Africa.

Begg, G. 1990., The wetlands of Natal (Part 4): policy proposals for the wetlands of Natal and KwaZulu. *Natal Town and Regional Planning report* 75.

Bender, D.J., Contreras, T.A., Fahrig, L., 1998. Habitat Loss and Population decline: A meta-analysis of the patch size effect. *Ecology* 79(2): 517-533

Bento, C. 2002. The status and prospects of Wattled Cranes *Grus carunculatus* in the Marromeu complex of the Zambezi Delta. Masters dissertation, Percy FitzPatrick Institute of African Ornithology, University of Cape Town.

Betts, M.G., Simon, N.P.P., Nocera, J.J., 2005. Point count summary statistics differentially predict reproductive activity in bird-habitat relationship studies. *J Ornithol* 146: 151-159.

Bibby, P.R., Shepherd, J.W., 1999. Monitoring land cover and land use for urban and regional planning. In: Longley, P.A.; Goodchild, M.F., Maquire, D.J., Rhinds, D.W., (eds). *Geographical Information Systems*. 2[nd] Ed Vol 2. London: Wiley & Sons.

Bollinger, E.K., Switzer, P.V, 2002. Modeling the impact of edge avoidance on avian nest densities in habitat fragments. *Ecological Applications* 12(6): 1567-1575.

Briggs, D.J., Courtney, F.M., 1989. *Agriculture and Environment. The Physical Geography of Temperate Agricultural systems.* Singapore: Longmore.

Burke, A., 1996. Wattled Crane (*Bugeranus carunculatus*).In: Meine, C.D., Archibald, G.W., (eds). *The Cranes: Status, survey and Conservation Action Plan.* Gland: IUCN.

Coverdale, B.M., McCann, K.I., 2005. Grassland loss in KwaZulu-Natal: Implications for Biodiversity Conservation. Endangered Widlife Trust Vision 13: 80-83

Díaz, M., González, E., Muñoz-Pulido, R., Naveso, M.N., 1996. Habitat selection patterns of Common Cranes *Grus grus* wintering in Holm Oak *Quercus ilex* dehesas of central Spain: Effects of human management. *Biological Conservation* 75 (2): 119-123.

Fairbanks, D.H., Thomson, M.W., 1996. Assessing land-cover map accuracy for the South African Land-Cover Database. *South African Journal of Scicence* (92): 465-470.

Filmer, R.J., Holtshausen, G.R., 1992. The Southern African Crane Census, 1985/1986. In: Porter, D.J., Craven, H.S., Johnson, D.N., Porter, M.J., (eds.). *Proceedings of the First South African Crane Conference*. Durban: The Southern African Crane Foundation.

Fletcher, R.J., 2005. Multiple edge effects and their implications in fragmented landscapes. *Journal of Animal Ecology* 74: 342-352.

Fresco, L.O., 1994. Imaginable futures: A contribution to thinking about land use planning. Introductory chapter. In: Fresco, L.O., Stroosnijder, L., Bouma, J., Van Keulen, H., (eds.). *The future of the land: Mobilising and integrating knowledge for land-use options*. West Sussex: John Wiley & Sons Ltd.

Gill, J.A., Sutherland, W.J., Watkinson, A.R., 1996. A method to quantify the effects of human disturbance on animal populations. *Journal of Applied Ecology* 33: 786-792.

Gilpin, M., Gall, A.E., Woodruff, D.S., 1992. Ecological dynamics and agricultural landscapes. *Agriculture, Ecosystems and Environment* 42 (1): 27-52.

Grenfell, M.C., Ellery, W.N., Preston-Whyte, R.A. 2005. Wetlands as early warning (eco)systems for water resource management. *Water SA* 31 (4): 465-472

Godron, M., Forman, R.T.T., 1983. Landscape modification and changing ecological characteristics. In: Mooney, H.A., Goodron, M., (eds). *Disturbance and Ecosystems: Components of Response*. New York: Springer-Verlag

Haney, J.C., Eiswerth, M.E., 1992. The plight of cranes: A case study for conserving biodiversity. In: Stahlecker, D.W. (ed). *Proceedings of the Sixth North American Crane Workshop*. Baraboo: International Crane Foundation.

Heath, S.C. Ballard, G. 2003. Patterns of Breeding Songbird Diversity and Occurrence in Riparian Habitats of the Eastern Sierra Nevada. In: Faber, P.M., (ed) 2003. California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration. Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento CA.

Hill, R.A., Hinsley, S.A., Bellamy, P.E., 2004. Intergrating Multiple Datasets for the remote quantification of Wolldland bird habitat quality. Proceedings of ISPRS Working Group V11/2. Available at: www.isprs.org/commision8/wg2/workshop_laser_forest/Hill.pdf. Accessed: 05th May 2006.

Konecny, G., 2003. *Geoinformation. Remote sensing, photogrammetry and geographic information systems*. London: Taylor & Francis.

Kotze, D.C., Breen, C.M., Quinn, N., 1995. Wetland losses in South Africa. In: Gowan, G.I., (ed) 1995. Wetlands of South Africa. Department of Environmental Affairs and Tourism, Pretoria, South Africa: 263-272.

Lacher, T.E., Jr., Slack, R.D., Coburn, L.M., Goldstein, M.I., 1999. The Role of Agroecosystems in Wildlife Biodiversity. In: Collins, W.W., Qualset, C.O., (eds). *Biodiversity in Agroecosystems.* Florida: CRC Press LLC.

Lavers, C.P., Haines-Young, R.H., 1996. Using models of bird abundance to predict the impact of current land-use and conservation policies in the flow country of Caithness and Sutherland, Northern Scotland. *Biological Conservation* 75 (1): 71-77.

Light, D.L., Jensen, J.R., (2002). Photogrammetric and remote sensing considerations. In: Bossler, J.D. (Ed). *Manual of Geospatial Science and Technology*. London: Taylor & Francis.

Ligon, J.D., Stacey, P.B., 1996. Land Use, Lag Times and the Detection of Demographic Change: The Case of the Acorn Woodpecker. *Conservation Biology* 10 (3): 840-846

Malan, G., Benn, G.A., 1999. Agricultural land-use patterns and the decline of the helmeted guineafowl *Numida meleagris* (Linnaeus 1766) in KwaZulu-Natal, South Africa. *Agriculture, Ecosystems and Environment* 73: 29-40.

Manel, S., Buckton, S.T., Ormerod, S.J., 2000. Testing large-scale hypotheses using surveys: the effects of land use on the habitats, invertebrates and birds of Himalayan rivers. *Journal of Applied Ecology* 37: 756-770

McCann, K.I., 2000. Briefing Book – Wattled Crane Population, habitat and Viability Analysis. Endangered Wildlife Trust.

McCann, K.I., 2001. Population status of South Africa's three crane species as of the end of 1999: based on a National Crane Census and regional aerial surveys. *Ostrich* Supplement 15: 126-129.

McCann, K., 2002. Using Wattled Cranes as an indicator of the hydrological functioning of,and threats to palustrine wetlands in South Africa. In Bernard, T., K. Mosepele & L. Ramberg (ed.). *Environmental monitoring of tropical and subtropical wetlands*: 92.

McCann, K.I., Benn, G., *In press*. Land use patterns within Wattled Crane (*Bugeranus carunculatus*) home ranges in an agricultural landscape in the KwaZulu-Natal province, South Africa.

McCann, K., Wilkins, H., 1995. A study of the annual biology and movement patterns of the three crane species in the Kwa-Zulu Natal Midlands. Eskom and Endangered Wildlife Trust Environmental Impact Assessment.

McGarigal, K., 1995. Fragstats 3.3. Spatial Pattern Analysis Program for Quantifying Landscape Structure. Corvalis, Oregon State University.

McGarigal, K., Marks, B. J., 1994. *Fragstats: Spatial Pattern analysis program for quantifying landscape structure*. Oregon State University, Corvalis.

McKernan, P., Hartvigsen, G., 2001. The Territory Distribution of Breeding Songbirds in the Roemer Arboretum, Geneseo, NY. *SUNY Geneseo Journal of Science and Mathematics* 2(1):7-15.

Meine, C. D., Archibald, G.W., (eds.). 1996. *The Cranes – Status, Survey and Conservation Action Plan.* Gland: IUCN.

Mondi Wetland Project. 2000. *Practical Wetland Management.* Wildlife and Environment Society of South Africa, South Africa.

Morrison, K., Bothma, J. du P., 1998. Wetland nesting sites of wattled and grey crowned cranes on the Steenkampsberg Plateau, South Africa. *South African Journal of Wildlife Research* 28(4): 110-120.

Neke, K.S., Du Plessis, M.A., 2004. The Threat of Transformation: Quantifying the Vulnerability of Grasslands in South Africa. *Conservation Biology* 18 (2): 466-477.

Newton, I., 1998. *Population limitation in birds.* London: Academic Press Limited.

O'Connor, R.J., Shrubb, M., 1986. *Farming and Birds.* London: Cambridge University Press.

Pienkowski, M.W., Bignal, E.M., Galbraith, C.A., Mccracken, D.I., Stillman, R.A., Boobyer, M.G., Curtis, D.J., 1996. A Simplified classification of land-type zones to assist the integration of biodiversity objectives in land-use policies. *Biological Conservation* 75(1): 11-25.

Piper, J.K., 1999. Natural Systems Agriculture. In: Collins, W.W., Qualset, C.O., (eds.). *Biodiversity in Agroecosystems.* Florida: CRC Press LLC.

Quinn, G.P., Keough, M.J., 2002. *Experimental design and data analysis for Biologists.* London: Cambridge University Press

Ratcliffe, C.S., Crowe, T.M., 2001. Declining populations of Helmeted Guineafowl in the midlands of KwaZulu-Natal, South Africa: a review of causes and remedies. *South African Journal of Wildlife Research* 31(3&4): 161-171.

Ronchini, S., 1998. *The impacts of land use changes on Wattled Crane breeding sites.* Masters thesis. School of Environment and Development, University of Natal, Pietermartizburg.

Scott-Shaw, C.R. 1999. *Rare and Threatened Plants of KwaZulu-Natal and neighbouring regions.* Pietermaritzburg, KwaZulu-Natal Nature Conservation Service.

SPSS Version 11.5. 2002. SPSS for Windows. Lead Technologies.

Tekelenburg, A., Prydatko, V., Alkemade, J.R.M., Schaub, D., Luhmann, E., Meijer, J.R., Undated. Assessment of Wild Biodiversity in Agricultural Land Use. First design and perspectives of a pressure-based Global Biodiversity Model. Available at: http://www.ulrmc.org.au/publication/envmanag/globio%20rivm%20ulrmc.pdf. Accessed: 16 September 2004.

Tivy, J., 1990. *Agricultural Ecology.* Essex, Longman Group UK.

Thompson, M.W., 1999. *South African National Land-Cover Database Project: Data Users Manual.* Final Report (Phase 1, 2 & 3). Division of Water, Environment and Forest Science, CSIR.

Thompson, M.W., Van Den Berg, H.M., Newby, T.S., Hoare, D., 2001. *Guideline Procedures for National Land-cover mapping and change monitoring.* Version 2. Terrestrial Resources and Environmental Management, CSIR and Agricultural Research Council. Available at: http://www.csir.co.za/websource/ptl0002/images/environmentek/nlc2000/appendices/25558-1.pdf. Accessed: 03 June 2005

Vander Haegen, W.M., Dobler, F.C., Peirce, D.J., 2000. Shrubsteppe Bird Response to Habitat and Landscape Variables in Eastern Washington, U.S.A. *Conservation Biology* 14(4): 1145-1160.

Winter, S., Morris, C.D., 2001. Mistbelt grassland fragmentation in the Umvoti Conservancy, KwaZulu-Natal, South Africa. *S.A. Journal of Botany* 67: 303-311

With, K.A., 2002. Landscape Connectivity and Metapopulation Dynamics. In: Gergel, S.E., Turner, M.G., *Learning Landscape Ecology: A practical guide to Concepts and Techniques.* New York: Springer.

Young, J.S., Hutto, R.L., 1998. Multivariate bird-habitat relationships models for some Northern Region bird species. Submitted as part of a final report for contract #53-0343-2-00207. Available at: http://avianscience.dbs.umt.edu/multivar.pdf.pdf. Accessed: 05th May 2006.

Young, J.S., Hutto, R.L., 2002. Use of Regional-scale Exploratory Studies to Determine Bird-habitat Relationships. In: Scott, J.M., Heglund, P.J., Morrison, M.L., Haufler, J.B., Raphael, M.G., Wall, W.A., Samson, F.B., (eds). Predicting species occurrences: issues of accuracy and scale. Covello, CA: Island Press.

Appendix 1: Land cover classes (Thomson *et. al.* 2001)

No	Land-Cover Class	Definition
1	Forest (indigenous)	All wooded areas with a tree canopy > 70 %. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forests (and woodlots)
2	Forest & Woodland (*rename* as Woodland)	All wooded areas with a tree canopy between 10 - 70%. A broad sparse - open – closed canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forests (and woodlots) Canopy cover density classes may be mapped if desired, based on sparse (< 40%), open (40 – 70 %), and closed (> 70 %).
3	Thicket, Bushland, Bush Clumps, High Fynbos	Communities typically composed of tall, woody, self-supporting, single or multi-stemmed plants (branching at or near the ground), with, in most cases no clearly definable structure. Total canopy cover is greater than 10%, with canopy heights between 2 – 5 metres. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species, especially along riparian zones). Presence of alien exotic species can be modelled spatially using broad principles of unlikely structural / temporal occurrences within a given vegetation biome or region. Dense bush encroachment would be included in this category. Canopy cover density classes may be mapped if desired, based on sparse (< 40%), open (40 – 70 %), and closed (> 70 %).
4	Shrubland and Low Fynbos	Communities dominated by low, woody, self supporting, multi-5stemmed plants, branching at or near the ground, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are low Fynbos, Karoo and Lesotho (alpine) communities.
5	Herbland	Communities dominated by low, woody, non-grass like plants, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are found in Namaqualand or "weed" dominated degraded areas.
6	Unimproved (natural)	**Grassland** All areas of grassland with < 10% tree and/or shrub canopy cover, and >0.1% total vegetation cover Dominated by grass like non woody rooted herbaceous plants *Essentially indigenous species growing under natural or semi-natural conditions.*
7	Improved Grassland	As above, except .... *Planted grassland, containing either indigenous or exotic species, growing under man-managed (including irrigated) conditions for grazing, hay or turf production, recreation (i.e. golf) etc*
8	Forest Plantations (Eucalyptus spp)	All areas of systematically planted, man-managed tree resources, composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials and woodlot / windbreaks of sufficient size to be identifiable on satellite imagery. Excludes all non-timber based plantations such as tea, sisal, citrus, nut crops etc.
9	Forest Plantations (Pine spp)	
10	Forest Plantations (Acacia spp)	
11	Forest Plantations (Other / mixed spp)	
12	Forest Plantations (clearfelled)	

13	Waterbodies	Areas of (generally permanent) open water. The category includes both natural and manmade waterbodies, which are either static or flowing, and fresh, brakish and salt water conditions. This category includes features such as rivers, major reservoirs, farm-level irrigation dams, permanent pans, lakes and lagoons.
14	Wetlands	Natural or artificial areas where the water level is permanently or temporarily at (or very near) the land surface, typically covered in either herbaceous or woody vegetation cover. The category includes fresh, brakish and salt water conditions. Examples include pans (with nonpermanent water cover), and reed-marsh or papyrus-swamp.
15	Bare Rock and Soil (natural)	Natural areas of exposed sand, soil or rock with no, or very little vegetation cover during any time of the year, (excluding agricultural fields with no crop cover, and open cast mines and quarries). Examples would include rock outcrops, beach sand, and dry river bed material.
16	Bare Rock and Soil (erosion : dongas / gullies)	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of current gully erosion processes. Typically located in association with areas of poor grassland cover along existing streamlines and / or on slightly steeper slopes than sheet erosion areas (i.e. greater than 6 degree slope). In some areas the full extent of donga activity may be obscured by either overhanging adjacent bushes, encroaching thorn bush, or, in the case of more stable dongas, by bush or grass cover along the actual streamline.
17	Bare Rock and Soil (erosion : sheet)	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of current sheet erosion processes. Typically located in association with areas of severe donga erosion and / or poor grassland cover (i.e. low image NDVI rating). In some areas the full extent of this process may be
18	Degraded Forest & Woodland	Permanent or near-permanent, man-induced areas of very low vegetation cover (i.e. removal of tree, bush, or herbaceous cover) *in comparison to the surrounding natural vegetation cover.* Typically associated with subsistence level agriculture and rural population centres, where overgrazing of livestock and / or wood-resource removal has been locally excessive. Often associated with severe soil erosion problems.
19	Degraded Thicket, Bushland, etc	
20	Degraded Shrubland and Low Fynbos	
21	Degraded Herbland	
22	Degraded Unimproved (natural) Grassland	
23	Cultivated, permanent, commercial, irrigated	Areas of land that are ploughed and / or prepared for raising crops (excluding timber production). Unless otherwise stated, includes areas currently under crop, fallow land, and land being prepared for planting. Class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such all sub-classes may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks), as well as farm infrastructure Several sub-classes are defined, based on the following parameters : **Commercial** : characterised by large, uniform, well managed field units (i.e. ± 50 ha), with the aim of supplying both regional, national and export markets. Often highly mechanised. **Semi-Commercial** : characterised by small – medium sized field units (i.e. ± 10 ha), within an intensively cultivated site, often in close proximity to rural population centres. Typically based on multi-cropping activities where annual (i.e. temporary crops) are produced for local markets. Can be irrigated by either mechanical means or gravity-fed channels and furrows. Medium - low levels of mechanisation. **Subsistence** : characterised by numerous small field units (less than ± 10 ha) in close proximity to rural population centres. Field units can either be grouped either intensive or widely spaced, depending on the extent of the area under cultivation and the proximity to rural dwellings and grazing areas. Includes both rainfed and irrigated (i.e.
24	Cultivated, permanent, commercial, dryland	
25	Cultivated, permanent, commercial, sugarcane	
26	Cultivated, temporary, commercial, irrigated	
27	Cultivated, temporary, commercial, dryland	
28	Cultivated, temporary, subsistence, dryland	

29	Cultivated, temporary, subsistence, irrigated	mechanical or gravityfed), multi-cropping of annuals, for either individual or local (i.e. village) markets. May include fallow and 'old fields', and some inter-field grazing areas (which are often classified as degraded). **Permanent** Crops : lands cultivated with crops that occupy the area for long periods and are not re-planted after harvest. Examples would include sugar cane and citrus orchards. Note in the case of sugar can, the growing season is typically 15 – 18 months per ratoon (i.e. harvest), with 2 – 3 ratoons possible before re-planting. Sugar cane is mapped as a separate crop type, and includes both large and small scale commercial activities, as well as fallow (i.e. burnt /cleared) areas. **Temporary** Crops : land under temporary crops (i.e. annuals) that are harvested at the completion of the growing season, and that will remain idle until re-planted. In general this refers to maize and soya bean cultivation within the Pongola catchment, although cotton is locally dominant amongst the larger commercial sugar cane plantation areas. Irrigated / Non-Irrigated : major irrigation schemes (i.e. areas supplied with water for agricultural purposes by means of pipes, overhead sprinklers, ditches or streams), and are often characterized
30	Urban / Built-up (residential)	Formal built-up areas, in which people reside on a permanent or near-permanent basis, identifiable by the high density of residential and associated infrastructure. Includes both towns, villages, and where applicable, the central nucleus of more open, rural clusters. Unless otherwise specified (and or mapped), will include both residential, commercial, industrial and transportation land-uses as well. Low density smallholdings frequently located on the urban fringe are mapped as a separate sub-classes, subdivided by the appropriate (level I) background vegetation type. If visible, individual farm units are also mapped as isolated smallholding units.
31	Urban / Built-up (rural cluster)	Areas of clustered rural dwellings (i.e. kraals) whose structural density is too low to be classified as a formal village, but are of sufficient level to be easily identifiable as such on satellite imagery. Small scale cultivation / garden plots often form a major spatial component, and are located amongst the residential structures.
32	Urban / Built-up (residential, formal suburbs)	Permanent residential structures, either single or multi-level, located within new or well established residential areas, i.e. '*garden-suburbs*', (often refers to 'middle-class' and 'upper class' residential areas). Includes both low and high building densities.
33	Urban / Built-up (residential, flatland)	Permanent residential structures, consisting mainly of 3 or more levels (often up to 10), resulting in a concentration of mid-to-high rise building, for example Hillbrow (Jhb) or Sunnyside (Pta).
34	Urban / Built-up (residential, mixed)	mixture ...
35	Urban / Built-up (residential, hostels)	Permanent residential structures, typically located in formal township districts, consisting mainly of 1 or 2 levels in concentrated block-like structures.
36	Urban / Built-up (residential, formal township)	Permanent (i.e. brick etc) structures (predominately single level), usually located on serviced sites within former black residential areas, laid out in a organised, pre-planned manner. Includes both low and high building densities.
37	Urban / Built-up (residential, informal township	Permanent / semi-permanent shack type dwellings (i.e. corrugated tin structures) laid out and established in an organised, pre-planned manner on both serviced and non-serviced sites. Includes both low and high building densities
38	Urban / Built-up (residential, informal squatter camp)	Non-permanent shack type dwellings (i.e. tin, cardboard, wood etc) typically established on an informal, adhoc basis, on non-serviced sites. Typically high building densities
39	Urban / Built-up (smallholdings, woodland ...)	see "residential' definition above ...
40	Urban / Built-up (smallholdings, thicket, bushland ...)	see "residential' definition above ...

41	Urban / Built-up (smallholdings, shrubland …)	see "residential' definition above ...
42	Urban / Built-up (smallholdings, grassland …)	see "residential' definition above ...
43	Urban / Built-up, (commercial, mercantile)	Non-residential areas used primarily for the conduct of commerce and other mercantile business, typically located in the central business district (CBD). Often consisting of a concentration of multi-level buildings, but also includes small commercial zones (i.e. spaza shops) within former black townships.
44	Urban / Built-up, (commercial, education, health, IT)	Non-residential, non-industrial sites or complexes associated with educational (i.e. schools, universities), business development centres such as industrial 'techno-parks', and / or social services (i.e. hospitals), often consisting of a concentration of multi-level buildings (Note : only mapped if clearly identifiable, otherwise included within '*commercial / mercantile*' or '*suburban*' categories.
45	Urban / Built-up, (industrial / transport : heavy)	Non-residential areas with major industrial (i.e. manufacture and/or processing of goods and products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards, train stations and airports (i.e. Johannesburg).
46	Urban / Built-up, (industrial / transport : light	Non-residential areas with major technology, manufacturing or transport related infrastructure. Examples would include light manufacturing units, warehouse dominated business development centres, and small airports (i.e. Lanseria). Also includes similar structures such as pig and battery hen breeding units.
47	Mines & Quarries (underground / subsurface mining)	Active or non-active underground or sub-surface based mining activities. Category includes all associated surface infrastructure etc
48	Mines & Quarries (surface-based mining)	Active or non-active surface-based mining activities. Includes both hardrock or sand quarry extraction sites, and opencast mining sites i.e. coal. Category includes all associated surface infrastructure.
49	Mines & Quarries (mine tailings, waste dumps)	Non-vegetated, exposed mining (and heavy industry) extraction or waste material

Appendix 2: Metric values calculated by FRAGSTATS for each patch class for both historic and active nest home ranges.

Nest Status	Land cover type	PAR	CA	%LAND	NP	PSSD	PSCV	TE	MNN	NNSD	NNCV	MPI	IJI
Historical	Optimal forage habitat	900.01	525.45	32.48	19	127.70	238.79	46.94	270	130	73	2 132.52	54.50
	Sub-optimal forage habitat	866.31	108.74	6.72	25	7.22	163.32	26.58	317	244	95	43.38	40.49
	Marginal forage habitat	629.29	194.90	12.05	10	35.29	127.82	24.51	287	261	80	145.11	52.55
	Excluded forage habitat	788.71	65.18	4.03	11	10.37	105.16	12.29	510	318	86	68.14	45.89
	Landscape												57.97
Active	Optimal forage habitat	847.32	548.85	33.92	17	127.53	229.97	46.84	195	124	81	2 514.45	53.96
	Sub-optimal forage habitat	904.30	110.25	6.81	28	7.60	174.48	27.29	281	212	94	48.25	41.98
	Marginal forage habitat	761.14	169.99	10.51	12	24.31	146.10	23.04	283	193	84	169.47	51.85
	Excluded forage habitat	773.97	52.16	3.22	9	8.52	102.88	9.75	489	260	81	33.81	44.31
	Landscape												57.33

Key for Appendix 2

PAR:	Mean Perimeter area ratio	
PI:	Proximity Index	
CA:	Class Area (ha) -	Mean area of each patch type
%LAND:	Percent of Landscape (%) -	Area occupied by each patch type in the landscape
NP:	Number of patches	
PSSD:	Patch size standard deviation	
PSCV:	Patch size Coefficient of variation -	Relative variability in patch size
TE:	Total edge (m) -	Total edge length or perimeter
MNN:	Mean Nearest Neighbour (m) -......	Mean distances between patches of the same type
NNSD:	Nearest Neighbour Standard Deviation	
NNCV:	Nearest Neighbour Coefficient of variation (%) -	Relative variability in nearest neighbour distance
MPI:	Mean Proximity Index -	Degree of isolation and fragmentation
IJI:	Interspersion and Juxtaposition -	Extent to which patch types are interspersed i.e. intermixing of units of different patch types based on patch adjacencies.

Appendix 3: P-Values for the various statistical tests performed

Description of land cover	Wald statistic	Degrees of freedom	Significance
Optimal forage habitat	0.044	1	0.833
Sub-optimal forage habitat	0.044	1	0.833
Marginal forage habitat	0.044	1	0.833
Excluded forage habitat	0.044	1	0.833

Distance to nest			
Optimal forage habitat	2.825	1	0.093
Sub-optimal forage habitat	1.658	1	0.198
Marginal forage habitat	0.877	1	0.349
Excluded forage habitat	13.717	1	0.014

Optimal forage habitat			
Class Area (ha)	1.529	1	0.216
Number of patches	4.925	1	0.026
Mean Nearest Neighbour	0.766	1	0.381
Area of patch	0.105	1	0.746
Perimeter area ratio	4.033	1	0.045

Sub-optimal forage habitat			
Class Area (ha)	0.010	1	0.918
Number of patches	0.065	1	0.799
Mean Nearest Neighbour	0.311	1	0.577
Area of patch	0.241	1	0.624
Perimeter area ratio	0.045	1	0.577

Marginal forage habitat			
Class Area (ha)	0.004	1	0.949
Number of patches	1.245	1	0.265
Mean Nearest Neighbour	0.001	1	0.979

Area of patch	0.912	1	0.339
Perimeter area ratio	0.854	1	0.355

Excluded forage habitat			
Class Area (ha)	0.002	1	0.966
Number of patches	2.396	1	0.122
Mean Nearest Neighbour	3.753	1	0.053
Area of patch	0.609	1	0.435
Perimeter area ratio	0.082	1	0.774

Core breeding area			
Optimal forage habitat	0.664	1	0.415
Sub-optimal forage habitat	0.164	1	0.686
Marginal forage habitat	5.987	1	0.14
Excluded forage habitat	2.725	1	0.099

Appendix 4: Patch statistics as calculated using Fragstats

Nest Status	Land cover type	Area of patch				Perimeter area-ratio				Euclidian nearest neighbour distance			
		Mean	Std Deviation	Range		Mean	Std Deviation	Range		Mean	Standard Deviation	Range	
Historical	1	27.78	142.31	1 573.23	(0-1 573.23)	1 014.93	1 278.77	7 977.62	(22.38-8 000.00)	126.16	231.88	3 239.65	(10.0-3 249.65)
	2	4.27	19.14	386.47	(0-386.47)	906.72	955.98	7 913.23	(86.77-8 000.00)	148.92	258.49	3 218.23	(10.0-3 228.23)
	3	19.23	56.79	683.05	(0-683.05)	887.64	1 442.80	7 952.97	(47.03-8 000.00)	159.22	325.07	2 903.82	(11.18-2 915.00)
	4	5.70	27.16	537.49	(0-537.49)	870.10	953.90	7 972.04	(27.96-8 000.00)	236.17	439.79	4 104.13	(10.0-4 114.13)
Active	1	31.46	155.22	1 604.01	(0-1 604.01)	924.22	1 063.57	7 983.18	(13.82-8 000.00)	120.63	174.87	2 558.16	(10.0-2 568.16)
	2	4.00	18.62	450.05	(0-450.05)	906.71	965.84	7 912.28	(87.72-8 000.00)	145.86	223.72	3 327.66	(10.0-3 337.66)
	3	14.75	40.75	358.95	(0-358.95)	850.31	1 107.72	7 950.23	(49.77-8 000.00)	159.54	320.77	3 597.08	(10.0-3 607.08)
	4	5.90	22.82	550.88	(0-550.88)	861.94	991.82	7 965.60	(34.40-8 000.00	263.90	451.68	3 893.82	(11.18-.3 905.00)

Key to Appendix 4

1 Optimal forage habitat
2 Sub-optimal forage habitat
3 Marginal forage habitat
4 Excluded forage habitat

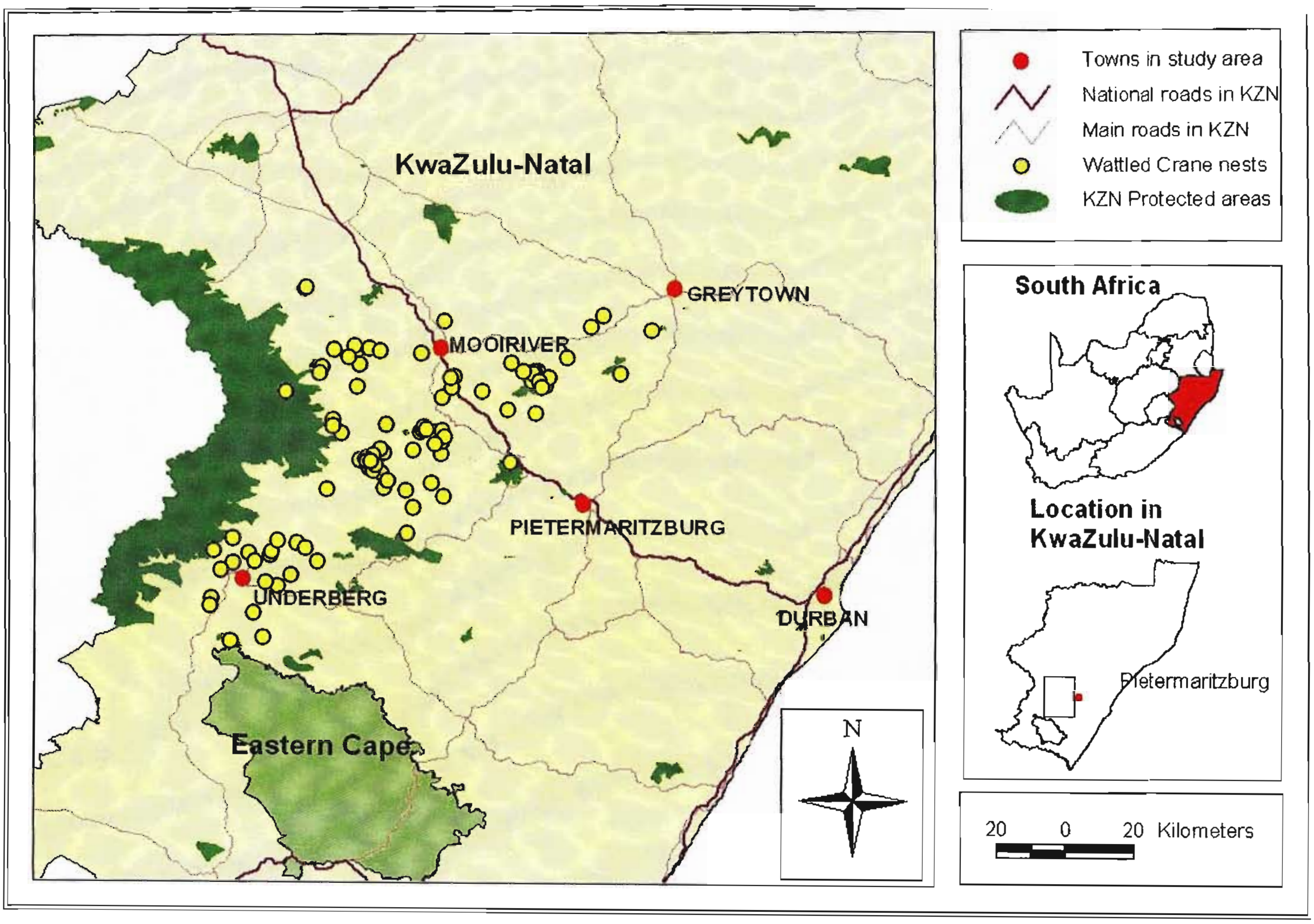

Figure 1: Map showing location of the study area in KwaZulu-Natal, South Africa

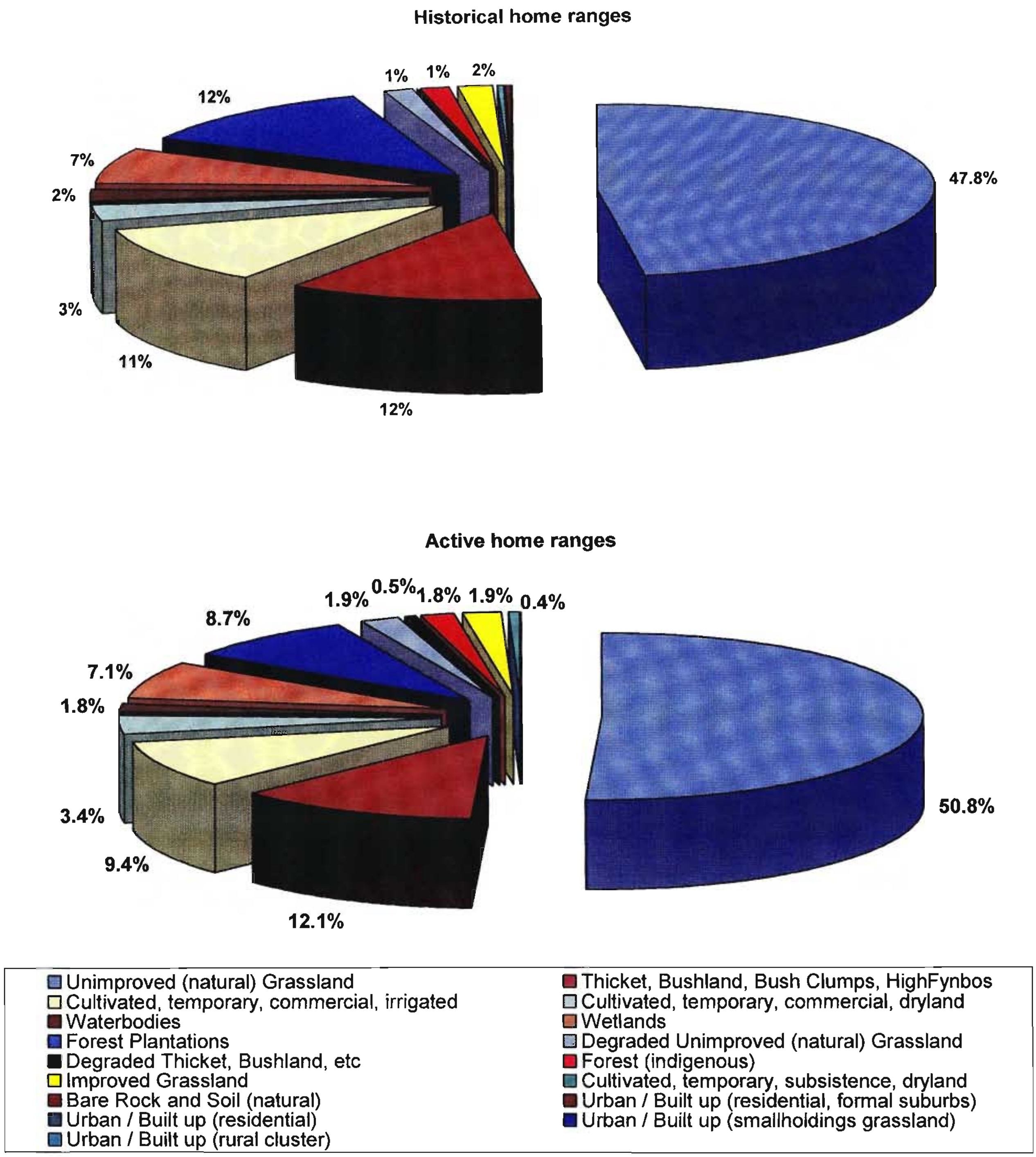

Figure 2: Breakdown of the home range composition for Active and Historical Wattled Crane nest sites

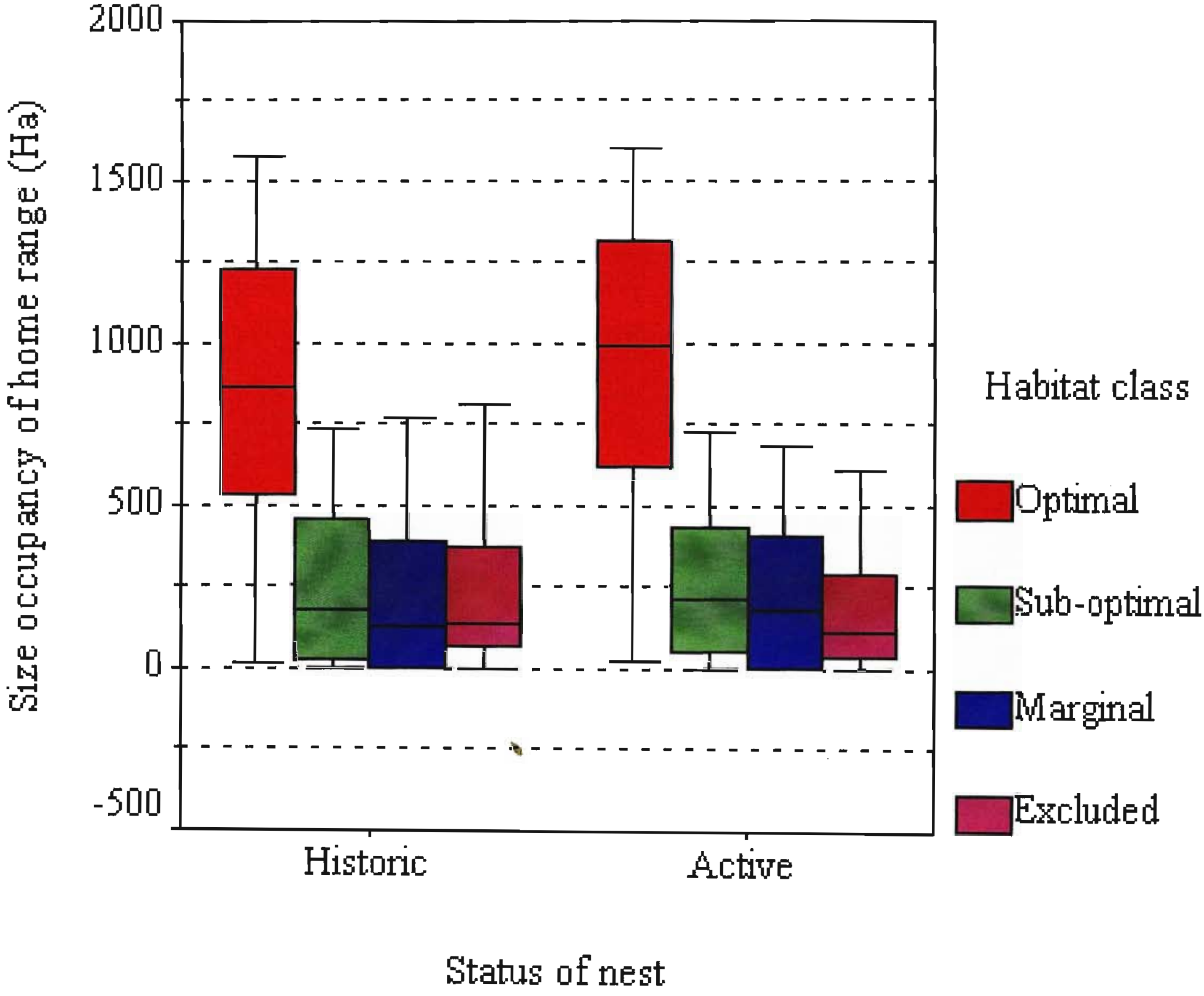

Figure 3: Boxplot of the home range composition for Active and Historical Wattled Crane nest sites

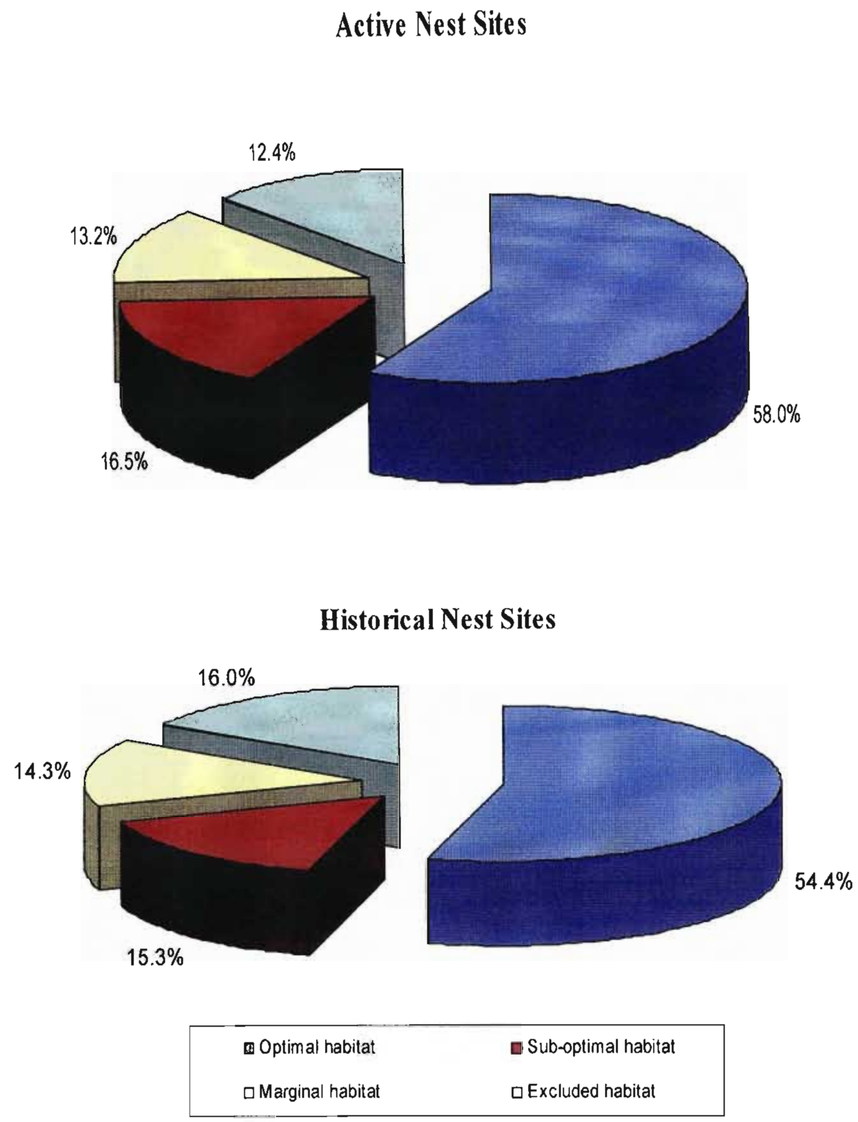

Figure 4: Breakdown of the home range composition for Active and Historical Wattled Crane nest sites

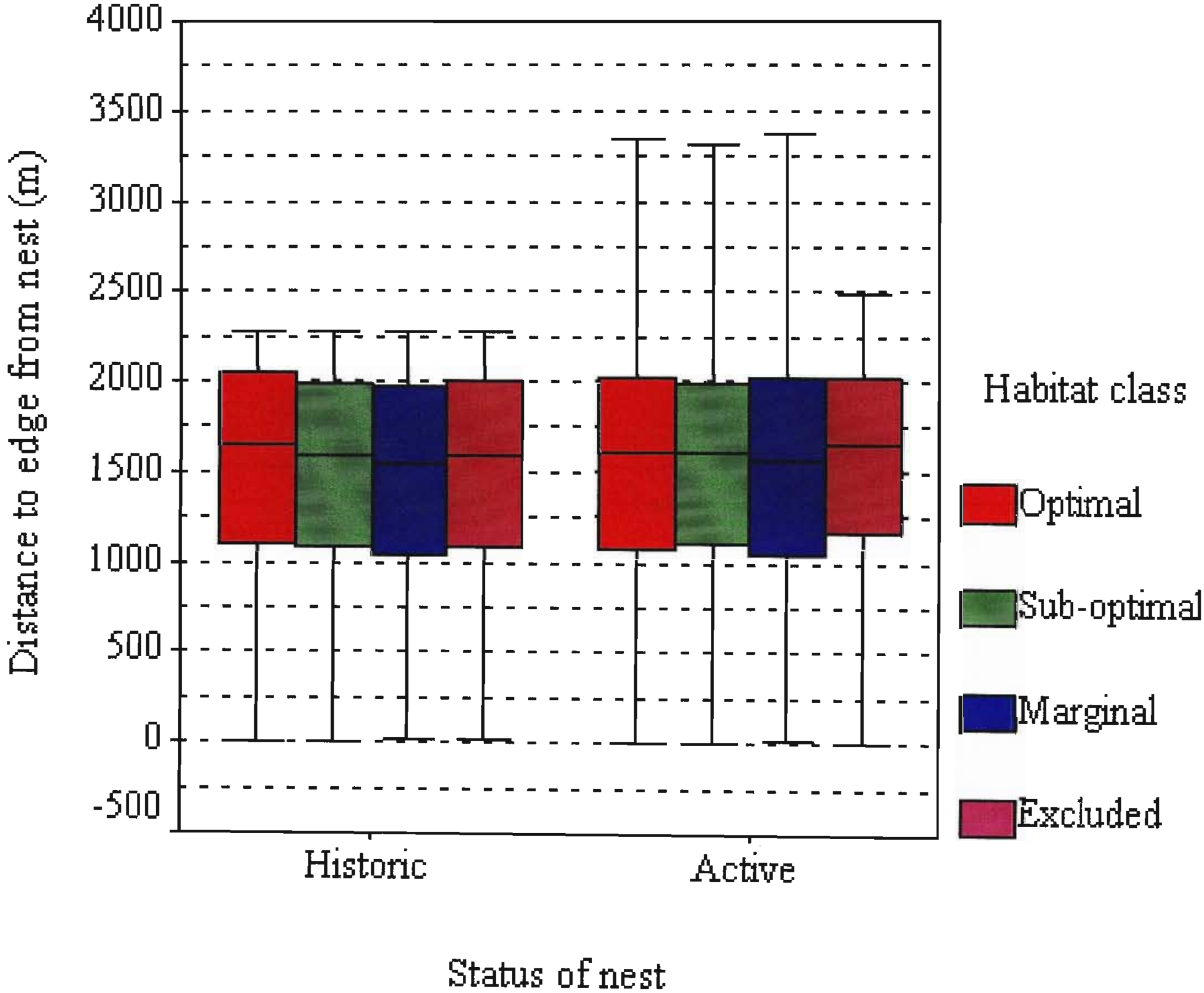

Figure 5: Boxplot showing the distance from the nest to various habitat cover classes

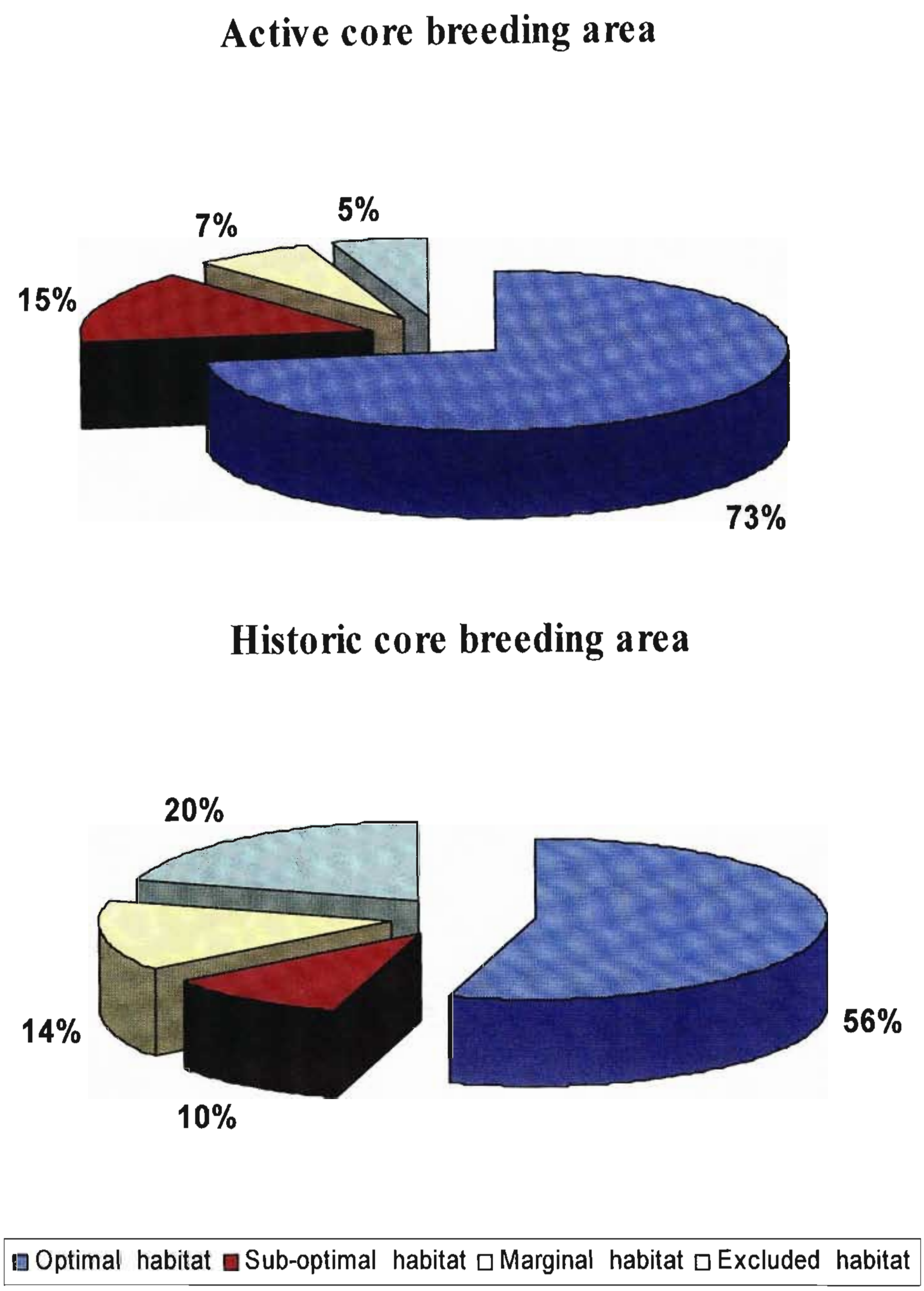

Figure 6: Breakdown of the habitat class types within the core breeding area

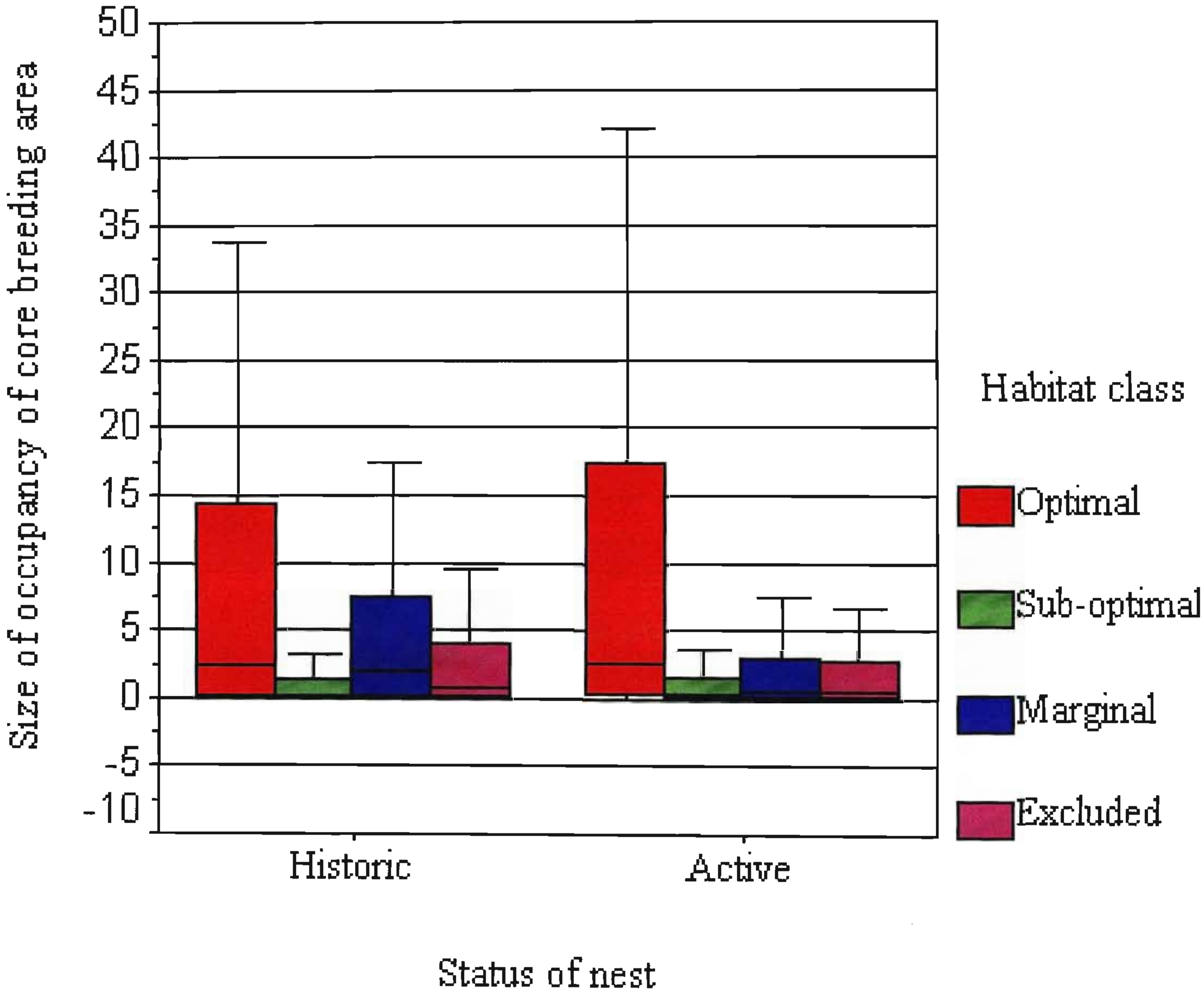

Figure 7: Box plot of the size of the core breeding area occupancy