Impacts of environmental change on large terrestrial bird species in South Africa: insights from citizen science data

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Declaration

I hereby declare that all the work presented in this thesis, titled "Impacts of environmental change on large terrestrial bird species in South Africa: insights from citizen science data", is my own, except where otherwise stated in the text. This thesis has not been submitted in whole or in part for a degree at any other university.

Signed in Cape Town in February 2012

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Sally Dorothy Hofmeyr

Dedication

For Dad,

for our ravaged land,

and of course,

this is for the birds

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Abstract

Title: Impacts of environmental change on large terrestrial bird species in South Africa: insights from citizen science data

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Large terrestrial bird species, especially cranes and bustards, have adapted to low intensity agriculture to varying degrees, but large-scale industrial agriculture is in general inimical to these species. Cranes are charismatic and well studied, but bustards are retiring and in general cryptically coloured, and little is known of most species. Of South Africa's 10 bustard species, two are endemic and three subspecies are endemic or near-endemic. Six species are threatened or near-threatened. Three crane species occur in South Africa, one of which is near-endemic; all are threatened. This thesis used data from two long-term public participation bird monitoring projects to improve our understanding of six of these 13 species. The first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992, and SABAP2, 2007–) provide two sets of presence/absence data which can be compared. The Coordinated Avifaunal Roadcounts (CAR; 1993–) project provides roadcount data spanning a similar period.

To assess the variability inherent in CAR data, additional, consecutive-day surveys of six CAR routes were conducted. The variability of the data was assessed by measuring the relative mean absolute difference between daily totals for route sections of a range of lengths, from 1 km up to the whole route. Species whose survey totals were most reliable were non-flocking, sedentary, and abundant, in descending order of importance. Exemplars were Northern Black Korhaan *Afrotis afraoides*, and Blue Crane *Anthropoides paradiseus*, especially in summer and where it was abundant. Flocking species, such as Helmeted Guineafowl *Numida meleagris*, and relatively uncommon species that range over large areas, such as Secretarybirds *Sagittarius serpentarius*, were the least reliably surveyed.

Methods for analysing CAR and SABAP data were developed and applied to data for the Southern Black Korhaan *A. afra*, Blue Crane, Denham's Bustard *Neotis denhami stanleyi*, Blue Korhaan *Eupodotis caerulescens*, Karoo Korhaan *E. vigorsii vigorsii* and Northern Black Korhaan.

CAR data were used to produce population trends for CAR precincts (groups of routes with similar habitat characteristics). Precincts and seasons (summer and winter) were analysed separately. Missing data were imputed using the Underhill index. Annual survey totals were converted to birds/100 km of road. These figures were plotted and a smoothed curve was fitted, using weighted linear regressions, to aid interpretation. Southern Black Korhaan totals decreased in the Western Cape and increased in the Eastern Cape. Blue Crane trends were increasing in the Western Cape and in one precinct in the Free State, but were decreasing or stable in other precincts. Denham's Bustard totals increased in one Eastern Cape and one Western Cape precinct, and decreased in one KwaZulu-Natal precinct. Trends for the remaining three korhaan species were stable or slightly increasing overall.

CAR habitat use data, separated by precinct and season, were summarised graphically and habitat selection was assessed. Habitat availability data were obtained from the National Land-Cover maps for 1994, 2000 and 2009. However, most habitat categories in these maps were different to those used in the CAR project. Habitat use and availability data were therefore summarised into two broad land-cover categories: natural and transformed. Habitat selection by each species was assessed using the Jacobs index. Southern and Northern Black Korhaans showed little preference for transformed habitats; in contrast, Blue Cranes selected transformed over natural habitats in most precincts and seasons. Other species showed intermediate levels of habitat selection. Preference for transformed habitats was strongest in the Fynbos biome and weakest in the Grassland biome.

Atlas reporting rates are related to abundance, although the exact nature of the relationship is not known. Therefore, changes in reporting rates for one species in one area for the same season or set of seasons are likely to reflect changes in abundance. Differences in reporting rates between SABAP1 and SABAP2 were analysed using maps. A statistic which takes into account the difference in reporting rates and sample sizes of checklists was calculated for each atlas grid cell. Grid cells were shaded according to the value of this statistic so as to highlight areas of potential conservation concern and those of possible population increase. SABAP comparison maps largely supported the CAR data population trends and thus provided useful information for areas not well covered by the CAR project. Reporting rates for the Southern Black Korhaan decreased in c. 80% of its range. Blue Crane reporting rates increased in the Fynbos and grassy Nama Karoo, but decreased in the rest of its range. The pattern was similar for the Denham's Bustard but the area of increase was smaller. Blue Korhaan

reporting rates decreased in most of the north-easterly third of its range, but were stable elsewhere. Karoo Korhaan reporting rates were approximately stable but SABAP2 coverage of this species' range was poor. Northern Black Korhaan reporting rates increased in the Free State but decreased slightly overall in the rest of the range that had good SABAP2 coverage.

Seasonal national population indices based CAR population trend data were calculated for each species. Data for each precinct were multiplied by five different sets of weights to produce five different indices, which were compared. The extent of coverage of each species' range by the CAR project was assessed. Southern Black Korhaan national population indices were inconclusive, while Blue Crane indices showed that the species had increased by 200–300% within the area covered by CAR over the period 1993–2010. Denham's Bustard indices showed the species to be stable or increasing slightly, although the range was relatively poorly covered by CAR. Indices for the remaining three korhaans suggested that the populations had remained stable or increased slightly overall, but all indices showed a high level of variability. The Blue Korhaan's range was well covered, but small proportions of the Karoo and Northern Black Korhaans' ranges were covered.

For the Southern Black Korhaan only, occupancy modelling was used to model occupancy and detection probabilities for SABAP1 and SABAP2 data for this species. Covariates used were biome and degree of land transformation. Occupancy declined over the species range as a whole, and detection probabilities declined strongly in three of the four biomes represented in the range, lending additional support to the conclusion that this species declined substantially in abundance and somewhat in range between SABAP1 and SABAP2.

Finally, results were synthesised and an analysis of the diversity of bustards throughout South Africa was conducted using SABAP1 and SABAP2 data. This analysis highlighted areas where CAR and SABAP2 coverage should be increased, to enable more confident assessment of the status of South African bustards. It was recommended that the 2012 threat categories for five of the study species remain the same, but that the Southern Black Korhaan (still listed as Least Concern in 2012) should be reclassified as Vulnerable.

Layout and contributions of co-authors and colleagues

This thesis consists of five main chapters, each written as a paper for submission to a journal. As a result some repetition, particularly in the methods sections, was inevitable. Tables and figures follow the text for each chapter, as would be done in a paper submitted for publication. The references are included at the end of each chapter. Professor Les Underhill commented on all drafts, and provided assistance with data analysis. Dr Phoebe Barnard commented on most drafts and provided general input for the thesis as a whole.

Chapter 2: I was responsible for the collection of much of the data used in this chapter; the remainder was collected by Graham Kletz and Ken Price. I also had assistants on my surveys of route KU01.

Chapter 3: Res Altwegg, Kristin Broms and Birgit Erni helped with the occupancy modelling used in this chapter. Res suggested using occupancy modelling, pointed me in the direction of relevant literature and software, and gave me much advice; Kristin helped me to get started by showing me how to use the software and providing me with initial R code to work from; Birgit gave me advice. Rene Navarro and Michael Brooks developed data queries that enabled me to extract the relevant data; Rene also helped with GIS work involved, and Michael developed most of the maps presented. Data were collected by CAR and SABAP participants. The National Land-Cover maps were provided by SANBI, and Fahiema Daniels and her GIS team helped me to manipulate the NLC2009 map.

Chapters 4, 5 and 6: Rene Navarro and Michael Brooks developed data queries that enabled me to extract the relevant data; Rene also helped with GIS work involved, and Michael developed most of the maps presented. Data were collected by CAR and SABAP participants. The National Land-Cover maps were provided by SANBI, and Fahiema Daniels and her GIS team helped me to manipulate the NLC2009 map.

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a basket-case if you weren't here, holding me together in your strong arms. Thank you, I love you so very much.

Oh and of course, to the birds: thank you for being there and enriching all of our lives by your presence. Thank you for being wild and free and having your own lives, passions and energies, completely independent of humans, but available for enriching our lives if only we open our eyes, ears and hearts enough to see you properly. You are enigmatic, mysterious, beautiful, and wild, and I hope with all my heart that we humans manage to stop destroying the earth in time for you to survive.

Chapter 1

Introduction

These elegant birds, in their stature, grace, and beauty, their wild fierce temperament, are striking metaphors for the vanishing wilderness of our once bountiful earth

~ P Matthiessen, 2001

Bustards are in general decline everywhere

~ NJ Collar, 1996

Large terrestrial birds, especially the bustards, are relatively poorly studied in South Africa, even though the group is unusually diverse in this country and there are several endemic and near-endemic species and subspecies. Globally, bustards and cranes are two of the most threatened groups of birds, and although the conservation status of many of South Africa's bustard species is not well understood, several are nonetheless listed as threatened or near-threatened on the South African and global Red Lists. Two long-term bird monitoring projects in South Africa are particularly well placed to increase our knowledge and understanding of the status of some of these birds. The principal aim of this thesis is to develop methods that enable us to make the most of the valuable data they produce.

This introduction aims to provide a solid backdrop to the thesis. Here I discuss the study species and the conservation issues relevant to large terrestrial birds in general, and to bustards and cranes in particular. I describe the study area and provide an overview of bird monitoring, focusing on the two monitoring projects which generated the data I analyse in this thesis. This section contains more detail about these projects than is appropriate for the individual chapters. The introduction also represents a convenient place to provide short descriptions of a set of study areas in South Africa, described as precincts. This eliminates the need to include descriptions of these areas in the chapters, helping to reduce the length of the thesis. I then provide a brief history of environmental change in South Africa. Finally I outline the aims and structure of the thesis.

Large terrestrial birds: bustards, cranes and others

Large terrestrial birds are loosely defined as birds that spend most of their time on the ground and away from water. Most species are easy to see due to their size. The group consists of non-passerines and includes families such as cranes (Gruidae), bustards and korhaans (Otididae), storks (Ciconiidae), gamebirds like francolins and spurfowl (Phasianidae) and guineafowl (Numididae). It also includes some atypical members of families such as geese (Anatidae), ibises (Threskiornithidae) and herons (Ardeidae) which are usually closely associated with water. In this thesis the focus is largely on cranes and bustards, but in Chapter 2 some other members of the group are considered as well.

Bustards and cranes are members of the same order, Gruiformes, but have been placed in separate suborders (Otididae and Gruidae respectively; Collar 1996). This classification reflects the accepted theory that they share the same evolutionary origins, but separated over 70 million years ago (Collar 1996). They are large (generally 50–175 cm in height) and they spend most of their time on the ground. While all crane species rely to some extent on wetlands, however, bustards are dryland birds (Archibald and Meine 1996, Collar 1996). Both groups tend to have varied diets, including a wide range of plant and animal matter, although the diets of wetland-specialised crane species are somewhat more specific, comprising mostly wetland vegetation (Archibald and Meine 1996, Collar 1996). All cranes exhibit specialised display behaviour, known as "antic" behaviour in the South African literature, and many bustards employ similarly complex display techniques, although in general not as dramatic and flamboyant as those of the cranes.

Other species more briefly discussed in this thesis are Black-headed Heron *Ardea melanocephala*, Helmeted Guineafowl *Numida meleagris*, Secretarybird *Sagittarius serpentarius*, Southern Bald Ibis *Geronticus calvus*, Spur-winged Goose *Plectropterus gambensis* and White Stork *Ciconia ciconia*.

Black-headed Herons are large herons generally found in open dryland habitats, although often not far from water. They roost and breed in colonies; however when foraging they are generally solitary or in small, loosely associated groups (Wanless 2005).

Helmeted Guineafowl are gamebirds typical of open grassland, scrub and savanna habitats, and they usually occur in flocks of between 15 and 40 individuals outside the breeding season (Ratcliffe 2005), although flock size can exceed 100 (CAR project unpubl. data).

Secretarybirds, the only species in their family, are evolutionarily and visually distinctive large, long-legged raptors. They are territorial; breeding pairs occupy territories of 20–230 km^2 (usually 50–60 km^2). They stride across their open grassland and savanna habitats, stamping on the ground to disturb prey items such as insects and reptiles, and killing them either with the bill or by stamping on them (Dean and Simmons 2005). In South Africa they are classified as Near-Threatened (Barnes 2000). The global classification was changed to Vulnerable in 2011 (BirdLife International 2012).

The Southern Bald Ibis, classified as Vulnerable both globally and in South Africa, nests in colonies on cliffs and generally feeds in flocks in open high altitude grassland habitats (Barnes 2005).

Spur-winged Geese are large ducks that spend much of their time in open grassland, karoo, Fynbos and agricultural habitats, although they gather and roost at waterbodies and usually breed near water (Colahan 2005). They occur in a range of group sizes, from singly to large flocks that congregate at bodies of water (CAR project unpubl. data).

White Storks are the only transcontinental migrants considered in this thesis. The majority of individuals are non-breeding summer visitors to South Africa which breed in the Palearctic. There is, however, a small breeding population in the Western Cape (Anderson 2005). White Stork numbers in South Africa vary annually depending on weather conditions farther north in Africa (Anderson 2005). They are found in various open habitats, especially agricultural land, and occur in a wide range of group sizes, from singly to very large flocks numbering in the thousands (CAR project unpubl. data).

Bustards

Bustards are described as "large to medium-sized stocky terrestrial birds, with long neck and legs", ranging from 40–120 cm tall (Collar 1996). They are found only in the Old World, and are most diverse in Africa; 21 of 25 species occur on this continent, and 17 are endemic to it. Ten occur in South Africa. While it is generally accepted that the bustard family originated over 70 million years ago (Collar 1996), more recent DNA analysis suggests a more recent origin (Pitra et al. 2002, Broders et al. 2003). Because of the preponderance of bustard species found in Africa, this continent is thought to be the centre of radiation of this group, and this theory has been corroborated by phylogenetic work (Pitra et al. 2002, Broders et al. 2003). The phylogeny of the Otididae has been a subject of debate for many years, and is still not settled (e.g. Pitra et al. 2002, Broders et al. 2003, Yang et al. 2010). Many bustard species are to some degree migratory, although whether any are completely so is not known (Collar 1996). Of the South African species, six (the "korhaans") are sedentary (although they may occasionally move locally to take advantage of newly available habitat or changing conditions) and the remaining four (the "bustards") display some combination of nomadism and local migration (Collar 1996, Allan 2005a, 2005c, 2005d, 2005f, 2005g, 2005h, 2005i, 2005j, 2005k, 2005m, Allan and Osborne 2005).

Two of the 10 South African bustards are endemic to the country: Southern Black Korhaan *Afrotis afra* and Blue Korhaan *Eupodotis caerulescens* (Allan 2005c, 2005k). Three subspecies are endemic or near-endemic: the southern subspecies of Denham's Bustard *Neotis denhami stanleyi*, formerly known as Stanley's Bustard; the south-eastern subspecies of the White-bellied Korhaan *E. senegalensis barrowii*, formerly known as Barrow's Korhaan, and the southern subspecies of the Karoo Korhaan *E. vigorsii vigorsii* (Allan 2005d, 2005f, 2005m). Of the 11 species occurring in the southern African region (defined as the region south of the Zambezi River, including the countries Namibia, Botswana, Zimbabwe, South Africa, Lesotho, Swaziland and Mozambique up to the Zambezi, following Hockey et al. 2005), four are endemic and three are near-endemic, extending only marginally beyond the boundaries of the region into southern Angola and/or Zambia (Allan 2005a, 2005c, 2005f, 2005g, 2005h, 2005i, 2005j, 2005k, 2005m, Allan and Osborne 2005).

Bustards are dryland birds, and all are cryptically coloured, at least in the females (Collar 1996). They have been divided into three groups which exhibit different life history strategies. In South Africa, the three large-bodied species (Kori Bustard *Ardeotis kori*, Ludwig's Bustard *N. ludwigii*, and Denham's Bustard) fall into the first group, which is characterised by a high degree of sexual dimorphism, a lek breeding system involving elaborate display rituals by the males, and females raising the young alone (Allan 1988, Collar 1996, Pitra et al. 2002). There have been several contradictory statements about mating systems in the past, mainly concerning Denham's Bustards, but it is now generally agreed that there is no evidence for long-term pair bonds or male involvement in breeding after mating (Allan 2005d). They generally occur in habitats featuring low vegetation, typified in South Africa by the Succulent Karoo, Nama Karoo, Fynbos and Grassland biomes, although Denham's and especially Kori Bustards do extend into the Savanna biome (Allan 2005d, 2005g, Allan and Osborne 2005). These three species are all gregarious and often occur in groups when not breeding. Although large gatherings have been observed, usually at sources of concentrated resources such as water holes or locust emergences, flocks are usually small and often single sex (Allan 2005d, 2005g, Allan and Osborne 2005).

The second and third groups comprise the smaller species, most of which are referred to as korhaans in this region. The species in the second group all have black bellies; the South African members are Southern Black Korhaan, Northern Black Korhaan *A. afraoides*, Red-crested Korhaan *Lophotis ruficrista* and Black-bellied Bustard *Lissotis melanogaster*. These korhaans tend to occur in habitats with taller vegetation than do most other bustards species (Kemp and Tarboton 1976, Collar 1996). In South Africa they occur in karoo, Fynbos and fairly dense Savanna. These species are highly sexually dimorphic, with boldly marked males and cryptic females; the males perform dramatic displays involving distinctive, far-carrying calls and visually arresting flights, and the females rear the young alone (Kemp and Tarboton 1976). Apart from females with young, the black-bellied species are rarely seen in groups.

The remaining three species, Karoo Korhaan, White-bellied Korhaan and Blue Korhaan, fall into the third group; all are pale-bellied and occur in areas of short, and in some cases sparse, vegetation (Kemp and Tarboton 1976, Collar 1996). In South Africa, they occur primarily in the Succulent Karoo, Nama Karoo and Grassland biomes (Allan 2005c, 2005f, 2005m). They are cryptic in colouration and less sexually dimorphic than the other groups of bustards. These species form pair bonds and occupy territories, and are often seen in small groups, usually assumed to consist of a breeding pair and one or more grown young (Kemp and Tarboton 1976, Allan 2005c, 2005f, 2005m). They are rarely seen alone. This group is also characterised by distinctive vocalisations, but these are thought to be territorial in nature, and there are no dramatic displays by the males (Collar 1996).

The five species I focus on in this thesis are those which occur in the south-eastern half of South Africa (Figure 1) and which were covered sufficiently by the Co-ordinated Avifaunal Roadcounts (CAR) project (see below): Blue Korhaan, Denham's Bustard, Karoo Korhaan, Northern Black Korhaan and Southern Black Korhaan. The ranges of the Blue Korhaan, Denham's Bustard and Southern Black Korhaan are reasonably well covered by the CAR project, while only small portions of the ranges of the Karoo and Northern Black Korhaans are covered. Data from the first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) are used to supplement knowledge about the status of these six species.

Cranes

There are 15 species of cranes, occurring on five continents: Africa, Asia, Australasia, Europe and North America. Three species occur in South Africa and six in Africa, one of these only as a non-breeding visitor (Archibald and Meine 1996). Cranes range in height from 90–176 cm, and are characterised by long necks and graceful forms, and by distinctive calling and displaying rituals. They all depend to some extent on wetlands, from the Siberian Crane *Grus leucogeranus* which is fully dependent on them, to the Demoiselle Crane *Anthropoides virgo* and Blue Crane *A. paradiseus*, which use wetlands only at night as roosting sites (Archibald and Meine 1996). Most species also forage to some degree in drier areas. Many of these have adapted[1] to and to some extent probably

[1] Where I refer to adaptation in this thesis, I use the term to indicate individuals adapting to local conditions rather than adaptation in the evolutionary sense.

benefitted from human cultivation of the land; all cranes except Siberian Cranes are known to feed in agricultural fields (Allan 1993). The more wetland-dependant species, however, have tended to suffer as a consequence of the widespread drainage of wetlands that has occurred during the process of land transformation for agriculture (Archibald and Meine 1996). Some crane species are migratory; others range from more or less sedentary to those which may engage in local seasonal movements. Migratory species may be extremely variable between populations in the extent of their migration. For example, while some populations of the Sandhill Crane *G. canadensis* do not migrate at all, others move thousands of kilometres between their breeding and wintering grounds annually (Allan 1997). Other crane species have substantially altered their migration patterns or ceased to migrate altogether in response to human alteration of their habitats.

Cranes tend to be generalist feeders, and their diets include a wide range of vegetation, invertebrates and small vertebrates (including reptiles, mammals, birds and fish; Archibald and Meine 1996). The wetland specialists tend to feed mostly on wetland fauna and flora, however. All cranes are gregarious to some extent, although they tend to take up isolated territories when breeding; they also all maintain long-term pair bonds. When not breeding, cranes congregate in flocks to roost at wetlands at night, and some species forage in flocks during the day (Archibald and Meine 1996). The only exceptions to this rule are the two crowned cranes (Grey Crowned Crane *Balearica regulorum* and Black Crowned Crane *B. pavonina*), which are the only cranes to roost in trees; Grey Crowned Cranes roost communally in a variety of habitats: in trees, on power utility structures and in wetlands (Archibald and Meine 1996, Allan 2005e).

Of the three species of crane that occur in South Africa, one, the Blue Crane, is endemic to southern Africa and virtually endemic to South Africa; there is a small and isolated breeding population outside this country's borders, in northern Namibia, in the Etosha Pan region (Allan 2005b). The other two species, Grey Crowned Crane and Wattled Crane *Bugeranus carunculatus*, are widespread throughout Africa but are threatened throughout all or much of their respective ranges (BirdLife International 2012). The Blue Crane is by far the most common and widespread of the cranes in South Africa, while the Wattled Crane, the most reliant on wetlands of the three, is the rarest, most sensitive to disturbance, and most restricted in range (Allan 2005b, 2005l). The Grey Crowned Crane is also dependent on wetlands for breeding, but tends to forage more in dry areas than the Wattled Crane does (Allan 2005e).

None of South Africa's crane species is truly migratory, although all undergo variable local seasonal movements (Archibald and Meine 1996). When breeding, Wattled Cranes are sedentary, but non-breeding birds form semi-nomadic flocks of "floaters" that move hundreds of kilometres (Allan 2005l). Grey Crowned Cranes in South Africa are thought to undergo some local seasonal movement within South Africa (Allan 2005e), but their movement patterns are not well understood. Various contradictory statements regarding the movements of Blue Cranes have been published (Allan 1997), but these remain unresolved. The Namibian population moves locally within the Etosha National Park; some subpopulations in South Africa are believed to undertake local (possibly partial) seasonal altitudinal migration, while others are thought to be largely sedentary, and some migration patterns appear to have changed markedly in the second half of the 20th century (Allan 1997, 2005b).

Conservation issues

Large terrestrial birds such as bustards and cranes are, in general, poorly protected by formal conservation through official protected areas (Young et al. 2003). In some species the area covered by individuals each day or over the course of a year is too large to protect; in others, some individuals may spend their entire adult lives within one breeding territory, but this is so large that protected areas could only ever conserve a small proportion of the population, too small to ensure the survival of the species. Many of these species have now adapted to and become dependent on using agricultural land to such an extent that they inevitably move out of natural areas at times, to feed in agricultural land (Johnson and Barnes 1986, Allan 1993). There they are at risk from poisoning, powerline collisions, fence entanglement and possibly hunting (e.g. Allan 2005b, 2005d, 2005g, Beilfuss et al. 2007, Shaw et al. 2010a, 2010b). A large proportion of the populations of these birds, therefore, exists in and depends on agricultural areas, whether they still breed and spend most of their time in the remnants of natural vegetation or spend much of their time feeding and even breeding in agricultural fields. Thus in order to monitor and protect these birds it is necessary to survey agricultural areas and attempt to gain an understanding of the aspects of agricultural land management that affect them, and then to work with land managers to develop and implement appropriate measures to protect the birds (Young et al. 2003).

Birds in agricultural landscapes

Bird species that live in and depend on farmland at least for part of the year, have undergone dramatic declines in population in many parts of the world (e.g. Newton 2004, Gillings et al. 2005, Gibbons et al. 2006, Amano and Yamaura 2007, Pocock 2010). This is particularly well studied in Great Britain, continental Europe and North America (e.g. Donald et al. 2001, Freemark and Kirk 2001, Murphy 2003, Newton 2004).

The consensus from this body of work is that the ongoing conversion of natural land to agriculture, and the intensification of traditional extensive farming systems to large-scale industrial agriculture are largely responsible for these declines (Donald et al. 2001, Green et al. 2005, Norris 2008, van Turnhout et al. 2010). Many processes have been identified as having a negative impact on farmland birds: removal of refuges such as hedgerows and uncultivated field margins, planting of crop monocultures over large areas, application of herbicides and insecticides which reduce plant and insect diversity, abandonment of traditional rotational farming systems which provided greater spatial and seasonal habitat diversity, destruction of nests, eggs and young by industrial agricultural machinery, and the introduction of irrigation (Pain and Pienkowski 1997, Suárez et al. 1997, Freemark and Kirk 2001, Brotons et al. 2004, Gibbons et al. 2006). The bird species which have declined as a result of these changes were in general previously common and widespread, and probably relatively tolerant of environmental change, and it has been suggested that they are therefore probably the tip of the iceberg of biodiversity loss from farmland, and that the problems that have lead to their decline are general and widespread (Tucker 1997). Birds, being mostly easy to see and identify, and at or near the top of the food chain, can be used as indicators of other biodiversity (see below and e.g. Donald et al. 2002, Gregory et al. 2004, Pereira and Cooper 2006), and the level of this diversity could be a useful measure of the sustainability of land management practices (Pain and Pienkowski 1997).

Most of the available literature on farmland birds focuses primarily on passerines; the largest birds included in most studies are gamebirds and waders (e.g. Donald et al. 2002, Newton 2004, Gillings et al. 2005, Kragten and Snoo 2008). In Europe, one crane and two bustard species still occur, however: Common Crane *Grus grus*, Little Bustard *Tetrax tetrax* and Great Bustard *Otis tarda*. Studies on their habitat use and the land management practices that favour their survival showed that traditional diverse, extensive agriculture is beneficial (e.g. Díaz et al. 1997, Suárez et al. 1997, Salamolard and Moreau 1999, Franco et al. 2000, Lane et al. 2001, Moreira et al. 2004, Silva et al. 2004, 2007, Morales et al. 2005, Palacin et al. 2012). Indeed, the bustards probably expanded their ranges when the original forest was cleared by prehistoric humans thousands of years ago (Collar 1996). However, modern intensive, low diversity, industrial agriculture is deleterious. There have been similar findings for an Asian species, the Bengal Florican *Houbaropsis bengalensis*; traditional farming methods were beneficial for the species because of the mosaic of habitats created (Baral et al. 2003, Gray et al. 2007).

In continental Europe and Great Britain birds adapted to agriculture over hundreds of years, and many species have come to rely on traditional low-intensity farming systems for their survival (e.g. Franco et al. 2000, Wolff et al. 2002, Moreira et al. 2005, Kleijn et al. 2009). This has led to "land sharing" conservation strategies, which focus on preserving these relatively low-yield farming systems for the sake of the wildlife which has come to depend on them. "Land sparing" is an alternative approach which involves adopting high-yield intensive agriculture in some areas in order to relieve the need to convert more land to agriculture, or to make available some of the less productive land for rehabilitation back to its natural state (Green et al. 2005). There has been much debate about whether land sharing or land sparing is likely to be more beneficial overall, largely focused on the developing world where there are still large areas of relatively pristine land available to conserve, but where intensive agriculture is also spreading rapidly (e.g. Vandermeer and Perfecto 2005, Ewers et al. 2009, Perfecto and Vandermeer 2010, Phalan et al. 2011). However, Wright et al. (2012) showed that even in developing countries a significant number of bird species (including two of the species I focus on in this thesis: Blue Crane and Blue Korhaan) is dependent on extensive farming systems. These farming systems should therefore form part of conservation strategies, as opposed to the usual approach within Africa, which is to regard only pristine land as worthy of conservation (Wright et al. 2012).

Southern African studies on farmland birds are relatively rare. Two studies found that in South Africa birds increase in diversity in areas of higher human population density, and attributed this to the greater diversity of habitats created by humans, but cautioned that this effect may not be long-term should the anthropogenically altered ecosystems not be sustainable (Fairbanks et al. 2002, Fairbanks 2004). Eagles in the karoo select against cultivated land and are more common in areas where both game and livestock are farmed than where only livestock is kept, irrespective of stocking rates (Machange et al. 2005). In Botswana, the Northern Black Korhaan, among other large grassland birds, declined in abundance outside of protected areas because of overgrazing by livestock, which caused bush encroachment (Herremans 1998). Grassland birds in the Mpumalanga province of South Africa, including 15 large terrestrial bird species, are significantly negatively affected by conversion of natural grasslands to commercial forestry (Allan et al. 1997b). Helmeted Guineafowl are positively associated with land-use diversity, using pastures free of agro-chemicals for cover and cereal crop fields where pesticides are used for feeding (Malan and Benn 1999). Blue Korhaans in the Wakkerstroom area prefer grassland which has been kept short, i.e. either burned or heavily grazed, and avoid cultivated land (Moreira 2004, 2006). Moreira (2004) also found that afforestation in the Wakkerstroom area is a threat to Denham's Bustards, and that agricultural intensification is a threat to White-bellied Korhaans and Black-bellied Bustards especially.

To my knowledge there are no southern African studies of the effects of agricultural intensification on birds in general. This may be less of an issue in this relatively recently cultivated region than in Europe because there has not been the same opportunity for bird species to adapt to farmland over thousands of years. However, as I show in this thesis, and as suggested by Young et al. (2003) and Wright et al. (2012), there are bird species which, in the absence of the large tracts of their original habitats, now depend to a great extent on farmland, including both modified and transformed land (discussed below). Agricultural intensification is likely on the whole to be to the detriment of these species, so this is an area which should be investigated, especially in light of plentiful statements that birds can be used as indicators of the health ecosystems in general (below and e.g. Herremans 1998, Morrison and Bothma 1998, Gregory et al. 2003, Gregory et al. 2004, Machange et al. 2005, Pereira and Cooper 2006, Greenwood 2007, Robledano et al. 2010).

Bustards

Although some bustard species have adapted to, and even in some cases benefitted from, anthropogenic changes to the natural vegetation, they are also sensitive to human disturbance and are vulnerable to a range of anthropogenic threats (Collar 1996). These include habitat destruction (mainly through conversion of natural vegetation to agriculture), habitat modification (mainly through agricultural intensification), powerline collisions (mostly affecting the larger species), hunting where it is still practised, and poisoning (these days usually inadvertent, e.g. through consumption of locusts which have been sprayed with insecticide). Some bustard species are among the most threatened birds in the world, especially the three species native to the Indian subcontinent, and this situation is largely ascribed to habitat loss and hunting (Collar 1996).

South African species are generally faring better than most, but there is cause for concern about some, and very little is known about this group overall. In a recent assessment of the threats to South African bustards, the species were ranked in order of priority for attention and the major threats to each species were listed (Table 1) (Allan and Anderson 2010). Habitat destruction and degradation is the most common threat listed (eight of the 10 species); other threats are human disturbance (four species), climate change (three species), powerline collisions (three species) and inadvertent poisoning by insecticides (two species). Allan and Anderson (2010) also recommend that the Red Data threat status of the Denham's Bustard and Southern Black Korhaan be revised. As of January 2012, South African species listed on the IUCN Red List were: Ludwig's Bustard (classified as Endangered in 2010), Denham's Bustard and Blue Korhaan (both classified as Near-Threatened in 2004; BirdLife International 2012). Locally, species included in the South African Red Data Book were: Denham's, Kori and Ludwig's Bustards and White-bellied Korhaan (all Vulnerable), Black-bellied Bustard and Blue Korhaan (both Near-Threatened; Barnes 2000). However, Allan and Anderson (2010) also stressed that much further investigation is needed. One of the aims of this thesis is to help fill this gap in knowledge.

Cranes

Most of the world's crane species are threatened to some degree. Of the 15 species, 11 are assigned global threat categories on the IUCN Red List: eight Vulnerable, two Endangered and one Critically Endangered (BirdLife International 2012). Despite their adaptation to some of man's alteration of natural habitats, these species' populations have declined largely because of anthropogenic destruction of or damage to wetlands and grasslands (Archibald and Meine 1996). All over the world wetlands have been and continue to be drained to make way for cultivation and other development, or overgrazed, burned, trampled and mown by and for livestock, with the result that most of the species originally inhabiting the wetlands are driven out or to local extinction. Cranes have therefore become a flagship species for the conservation of wetlands, not only because of their size and charisma but also because they are only the most obvious of many wetland-dependant species that are under threat from the destruction of wetlands (Archibald and Meine 1996, Meine and Archibald 1996).

Many large conservation initiatives and public awareness campaigns have centred on cranes, and these species have provided an effective focus for environmental education (Meine and Archibald 1996). One such example is the Crane Study Group, launched in South Africa in 1978 (Anonymous 1978). This group evolved over the years through various incarnations, most notably the South African Crane Working Group, to today's African Crane Conservation Programme, which is a partnership between the Endangered Wildlife Trust and the International Crane Foundation, and carries out many projects aimed at monitoring and conserving Africa's crane species (Endangered Wildlife Trust 2012). One of the best known and most successful wildlife conservation efforts to date anywhere in the world is that centred on the Whooping Crane *Grus americana* in North America (Archibald and Meine 1996). By the early 20th century the species had almost been exterminated by a combination of habitat destruction, hunting and egg collection, and by the mid-twentieth century only a tiny population of less than 20 birds survived in the wild. Through habitat protection, captive breeding and education of the public, conservation initiatives saved the species from extinction, and the population is slowly recovering (Archibald and Meine 1996, BirdLife International 2012). These conservation efforts not only served to bring the Whooping Crane back from the brink of extinction, they also helped to increase public awareness of the environmental problems that lead to the crane's near-total disappearance.

Other major threats to cranes include hunting, powerline collisions, disturbance and persecution by farmers (Archibald and Meine 1996, BirdLife International 2012). The latter is either deliberate, because the birds are seen as pests, or inadvertent, when cranes consume poisons intended for other pest species. In South Africa the principal threats to cranes are habitat loss through drainage of wetlands and conversion of grasslands to afforestation or intensive agriculture, poisoning, collecting for the illegal pet trade and powerline collisions (Barnes 2000). All three species are classified as Vulnerable globally (BirdLife International 2012), and in South Africa the Blue Crane and Grey Crowned Crane are classified as Vulnerable, while the Wattled Crane is Critically Endangered (Barnes 2000, Beilfuss et al. 2007). The South African populations of each species are estimated as at least 25 500 Blue Cranes, more than 4 000 Grey Crowned Cranes and c. 240 Wattled Cranes (Beilfuss et al. 2007).

Study area

This study makes use of data from the CAR project, SABAP1 and SABAP2. These data were collected exclusively in South Africa; the CAR project operated only in this country, and of the two bird atlas projects, only SABAP1 included data collected in other southern African countries. Comparison of atlas data from SABAP2 with that from SABAP1 is therefore impossible outside of South Africa until such time as data collection begins in other countries.

The CAR project covered much of the south-eastern half of the country (Figure 1), concentrating on areas transformed by agriculture and where large terrestrial birds are more common. Much of the north-east of the country is relatively unsuitable for most large terrestrial birds, which in general prefer open landscapes with low vegetation. The north-west of South Africa, although it is the core of the range of several species the CAR project monitors (Ludwig's Bustard, Karoo Korhaan, Northern Black Korhaan) and home to several other "CAR species", was unfortunately poorly covered because of a low density of suitable roads and willing volunteers.

The parts of the country which were most extensively covered are the Overberg and Swartland regions in the Western Cape province, most of the Free State province, parts of KwaZulu-Natal and, most recently, Gauteng. The Eastern Cape, Mpumalanga and other parts of the Western Cape are not as thoroughly covered. In general, lack of coverage in these areas is also because of a lack of roads and potential observers. A section of the Northern Cape, in the south-west of that province, is relatively well covered, although participation declined in 2008 and 2009, with the result that many routes had to be excluded from my population trend analyses due to having been surveyed an insufficient number of times (details are provided in the relevant chapters).

Apart from the increasing influence of anthropogenic factors, habitat suitability for birds and most other organisms is largely determined by vegetation, climate and topography. I now provide brief descriptions of these aspects of the study area, as they relate to my study species and the data I use. They are thoroughly described, particularly as they relate to the distributions and life histories of birds, by Allan et al. (1997), and much of the material I present here is drawn from that excellent text.

Topography

South Africa's topography is dominated by the Great Escarpment, which roughly follows the coast, but with a broad belt 50–200 km wide between it and the coast (Allan et al.

1997a). The Great Escarpment is higher in the east than in the west, with altitudes of more than 1 800 m in much of the Drakensberg range. The highest parts of the country are in these mountains along the eastern border of Lesotho, and reach more than 3 000 m above sea level (ASL) on the tallest peaks. The interior of the country, that part inland of the Great Escarpment, forms the Central Plateau, which slopes downwards from east to west. Approximately the eastern half of the Central Plateau, and a strip along the southern section of the Great Escarpment, is above 1 200 m in altitude, with the western half being between 600 m and 1 200 m ASL. In general the higher altitude part is dominated by grasslands, and the lower by karoo vegetation (see below). The part of this plateau above 1 500 m ASL is known as the highveld, and although much of it is characterised by flat or gently rolling topography, it is punctuated in places by smaller mountain ranges, such the fold mountains of the Magaliesberg in Gauteng, and in other places by occasional flat-topped mesas and buttes. In the lower altitude western half of the plateau the topography is largely flat, with mesas (known as “koppies”) liberally scattered around (Allan et al. 1997a). These generally small, isolated, flat-topped hills and mountains are the resistant remnants of an earlier higher plateau, most of which has eroded away.

The margin between the Great Escarpment and the coast is far from uniform. In the south-west (Western and Eastern Cape) it is characterised by many small ranges of fold mountains running roughly parallel to the coast, which create rain shadows and barriers to plant species (Allan et al. 1997a). Many different, highly diverse vegetation types, both Fynbos and Succulent Karoo, exist as a result of this complicated topography, although the bird diversity associated with this region is surprisingly low (see below). Along the west coast the coastal margin is largely flat and relatively low-altitude (below 600 m ASL). In the east of the country the coastal margin is characterised by undulating Grassland-dominated topography from the south up to northern KwaZulu-Natal, and by the flatter, subtropical to tropical “Lowveld” Savanna north of that (Allan et al. 1997a).

Large terrestrial birds tend to prefer flatter topography in general, but occur at a range of altitudes from low coastal plains (e.g. Denham’s Bustards) to high altitude grasslands (e.g. Blue Korhaans) (Allan 2005c, 2005d). Some of them, like Blue Korhaans, occur within a relatively narrow range of altitudes, while others, such as Denham’s Bustards, are fairly cosmopolitan in that respect, ranging from coastal lowlands to the high foothills of the Drakensberg.

Climate

Climate is probably the primary determinant of habitat suitability for birds, because it not only determines the temperatures which must be survived and the availability of moisture, but also largely the type of vegetation which occurs in an area. The most important determinant of the type of vegetation is probably the quantity and seasonality of rainfall (Allan et al. 1997a).

Mean annual rainfall (MAR) in South Africa tends to decrease from east to west, and more than half of the country has a MAR of less than 500 mm and is therefore classified as semi-arid to arid (Allan et al. 1997a, Schulze 2007). However areas to the east of the Drakensberg escarpment, and a narrow strip along the south coast down to the Cape Peninsula in the south-western corner of the country, receive more than 800 mm of rainfall annually (Schulze 2007). Most of the country receives the majority of its rainfall in summer, but a broad strip of land down the west coast, widening towards the south coast, receives mainly winter rainfall, and there is a band of overlap between the two zones, where similar quantities of rain fall in summer and winter. A strip along the south coast also receives rain all year round (Schulze 2007). The winter rainfall regions are characterised by very different vegetation to the summer rainfall regions; the latter are dominated by grass, with varying proportions of trees and brush, while the former are dominated by sclerophyllous shrubs (Allan et al. 1997a). In general the degree of variability in annual rainfall is negatively correlated with the quantity thereof, so organisms that inhabit the dry western half of the country have to be able to cope with erratic rainfall and frequent long droughts, and take advantage of occasional unpredictable gluts of food when large rainfall events do occur. The timing of birds' breeding is very much affected by seasonal rainfall, and species whose ranges span both summer and winter rainfall areas tend to have different peak breeding seasons in these areas (Allan et al. 1997a).

Temperatures in South Africa are generally warm to hot, with mean annual temperatures of 15ºC over the majority of the country, although large parts of the centre of the country regularly experience temperatures below freezing in winter (Schulze 2007). In terms of mean annual temperature the hottest region is a strip up the eastern border of the country from northern KwaZulu-Natal northwards, although more extreme daily maximum temperatures are experienced over much of the Northern Cape. The higher average in the north-east is caused by higher minima, rather than higher maxima, than in the Northern Cape (Schulze 2007). Like most desert and semi-desert regions, the arid and semi-arid parts of South Africa tend to experience greater daily temperature ranges than the moister and coastal areas, where temperatures are moderated by the higher humidity and the ocean currents (Allan et al. 1997a, Schulze 2007). That being said, the day-to-day variability in temperatures in the arid and semi-arid regions is low, while in coastal regions conditions may change markedly from one day to the next.

The CAR project does not operate in the hottest parts of South Africa, and the mean annual temperature is between 14ºC and 18ºC in most of the precincts (Schulze 2007). Average maximum temperatures in summer range between 25ºC and 33ºC for much of the area, the hottest areas being in the karoo and northern KwaZulu-Natal, and the coolest (average daily maxima between 23ºC and 25ºC) in the higher altitude areas in Mpumalanga and southern KwaZulu-Natal. In winter the average maximum temperatures range between 15ºC and 23ºC in most of the area covered by CAR, the coldest area being the north-eastern Eastern Cape, and the warmest northern KwaZulu-Natal (Schulze 2007). In the north-eastern Eastern Cape and high altitude parts of southern and western KwaZulu-Natal average minimum temperatures in winter are below zero, but in low altitude coastal regions they are around 8–10 ºC.

Biomes

Vegetation is the primary descriptor of habitat for most species, including most birds. Bird habitats are generally defined in terms of the type of vegetation they prefer, as well as topographical features, which are generally reflected in the type of vegetation as well (e.g. montane vegetation is usually fairly distinct from low altitude vegetation) (Allan et al. 1997a). Vegetation is determined primarily by climate, but also by topography and soil (as well as, increasingly, anthropogenic factors, some of which are discussed below). The biome is the broadest level of categorisation of natural vegetation available and is sufficient for my purposes in this thesis. Under the currently accepted classification of vegetation types, that developed by Mucina and Rutherford (2006), South Africa has nine biomes (Figure 2). The three largest biomes in terms of area are Grassland, Savanna and Nama Karoo (Mucina and Rutherford 2006). The smallest are Forest, remaining only in a few small fragments, mostly in montane areas, and Desert, of which there is only a narrow strip in South Africa, along the southern Namibian border.

Large terrestrial birds typically prefer open, low vegetation, which allows them unrestricted movement and facilitates predator detection and evasion. The most important biomes for the species I focus on here are Grassland, Nama Karoo and Fynbos; Savanna and Succulent Karoo are also of importance to some of them.

Grassland is self-explanatory: open vegetation dominated by grass and with very few, if any, trees or bushes (although there is generally a wide diversity of small herbaceous plants interspersed with the grass). It ranges from relatively low altitudes up to high altitude montane grasslands. A large proportion of this biome has been transformed for agriculture, afforestation and human settlement (Allan et al. 1997a). The factors that combine to create and maintain grassland are relatively high summer rainfall, frequent fires, grazing and frost, all of which prevent shrubs and trees from becoming established.

The karoo biomes are classified as semi-desert (Young et al. 2003) and occur in the driest parts of the country. Karoo vegetation is characterised by small shrubs, mainly succulent in the Succulent Karoo. The Nama Karoo has a grassy component as well, increasing from west to east, and there is a broad ecotone between this biome and Grassland which is known as "grassy karoo" (Allan et al. 1997a). Tree cover is almost non-existent except in watercourses and in the Little Karoo region of the Succulent Karoo biome. Succulent Karoo occurs in the winter and mixed rainfall regions, and Nama Karoo only in the summer rainfall region.

Fynbos is the least open of these habitats, consisting largely of dense, shrubby vegetation between knee and waist height, and in renosterveld it is considerably taller and denser (Allan et al. 1997a, Young et al. 2003). There is an exceedingly high level of plant diversity and endemism in this biome, but bird diversity is relatively low in comparison with the other biomes (Allan et al. 1997a), possibly because of a low diversity of vegetation structure, the dense nature of the vegetation, poor palatability of the plant types typical of this vegetation, and a comparatively low diversity of insects. Although it was in this biome that the CAR project started, it is actually not a highly suitable habitat for most large terrestrial birds. Blue Cranes have only moved into the biome since large portions of it were converted to agriculture (Chapter 4), and the Denham's Bustard, which does occur in the biome naturally, now spends much of its time in this biome in agricultural land (Chapter 5). Karoo Korhaans have, like the Blue Crane, moved into the area only since it was largely converted to a more open habitat through agriculture (Chapter 6). The Southern Black Korhaan (Chapter 3) is the only one of the six species I focus on that shows a strong preference for this vegetation, especially renosterveld (Uys 1988).

The Savanna biome is characterised by a grassy understorey and a variable upperstorey of trees and large shrubs (Allan et al. 1997a). The level of canopy cover varies from sparse (generally in the west of the biome) to almost closed (generally in the east). Most large terrestrial birds, if they use this biome at all, use only the parts with sparse tree cover, although the Red-crested Korhaan and Black-bellied Bustard are exceptions to this rule.

For obvious reasons, the CAR project's routes are to be found mainly in the Grassland, Nama Karoo and Fynbos biomes (Figure 1). Some important CAR species do occur in the Succulent Karoo, but as discussed above it has not thus far been possible to establish CAR routes in this area.

Bird monitoring

History

The earliest known example of collaborative bird monitoring is the collection of spring arrival dates for migrants by a professor in Finland in 1749 (Greenwood 2007). This ongoing data collection project continues, and represents by far the longest such data series anywhere in the world. The first coordinated bird monitoring project, the annual Christmas Bird Count (CBC) in the USA, began in 1900 (Silvertown 2009). This project is also ongoing, and is run by the National Audubon Society; in the early 2000s, 60 000–80 000 participants took part annually (Cohn 2008). Bird monitoring projects of various kinds, of which the CBC is one, have been growing in number since 1900, especially since the 1950s, and at the start of the 21st century there were at least 12 nationwide bird monitoring programmes in Britain alone (Underhill and Gibbons 2002). It has even been suggested that there are too many such projects currently running in North America, and that in some cases the participants' skills and enthusiasm might be put to better use in other types of projects (Bart 2005)! There are various broad categories of bird monitoring, including those that collect census data, those that compile checklists, bird ringing schemes (which typically collect biometric data, moult data and may collect some form of census data) and those that collect nest or breeding records (Underhill et al. 1991). I focus here on census and checklist projects, because the two projects upon whose data I draw for this thesis belong to those categories.

A range of census methods exists, some of which aim to count all birds in a given location (usually restricted to waterbirds and breeding colonies of seabirds which are confined to relatively small, well-defined areas such as waterbodies or islands), and others which aim to count a representative sample of the population using scientific sampling methods (Underhill et al. 1991). The latter kind includes point counts (counting birds from fixed points for a fixed period of time), transect counts (counting birds along a strip of fixed width), territory mapping (mapping the territories of resident birds in a predetermined area) and distance sampling (measuring the distance from the observer to the birds while either standing at a fixed point or moving along a transect) (Verner 1985, Rosenstock et al. 2002). In all cases it is important that a strict count protocol is established and adhered to, so as not to violate the assumptions on which the analysis of such data are based. One form of transect counts is roadcounts, where the observer drives along a length of road in a motor vehicle and counts birds along the way. The first known standardised roadcounts of birds were conducted by a couple and their daughter in the USA in 1920–21; they published an article about their method and all the information that could be gained from it, and recommended it as a worthwhile method of bird monitoring (Nice and Nice 1921).

In South Africa a wide range of bird monitoring projects has been carried out, starting in 1948 when bird ringing began (Underhill et al. 1991). Census data have been collected since the early 1950s. In the early years most such counts were of waterbirds and seabirds, and all birds present on the island or at the waterbody being surveyed were counted. Terrestrial birds are more difficult to survey completely because they are not usually restricted to small well-defined areas, so they need to be surveyed using sampling methods as described above (Underhill et al. 1991). The count totals thus obtained are generally assumed to be proportional to population density and as such are treated as an index of abundance. In contrast to the large-scale, long-term terrestrial bird census projects carried out in, for example, North America and Britain, the only census surveys of terrestrial birds in South Africa prior to 1993 were small-scale and short-term by comparison. This is attributed to the fact that conditions in southern Africa are less predictable than in the temperate northern hemisphere, and erratic climatic conditions as well as challenging natural vegetation make it difficult to apply the methods used there without modification (Underhill et al. 1991, Bennun 2000). The first records of systematic terrestrial bird surveys in South Africa come from the 1960s; in 1965 a farmer counted birds on his land along transects through specific habitat types, recruiting local children as assistants, and in 1968 results of roadcounts of conspicuous birds such as raptors and cranes were published (Siegfried 1968, 1985, Underhill et al. 1991). Other bird census projects included transect counts and territory mapping, point counts before and after a planned fire, counts of birds seen in gardens, and stork and crane censuses in the mid-1980s, which involved not only sightings made on foot and on roadcounts but also aerial surveys (Underhill et al. 1991). The first southern African bird census project to involve volunteers and allow comparisons over time was the Namibian raptor roadcount, which ran from 1977 until 1984 (Underhill et al. 1991). From 1988 to 1993 a roadcount project was carried out with the aim of assessing the status of Blue Crane and bustard populations in the former south-western Cape Province (Allan 1993), and this led to the establishment of the CAR project. The CAR project, described in detail below, remains the only large-scale, long-term bird monitoring project to census terrestrial birds in South Africa, although there are other smaller-scale projects that monitor more restricted groups of species in smaller areas, such as the ongoing annual aerial surveys of cranes in KwaZulu-Natal (Smith et al. 2010).

Another type of bird monitoring that began to develop in the 1950s is bird atlasing, which was based on the principle of collecting checklists of species for a given area. Atlas, in this context, has come to mean a set of distribution maps for a group of organisms, and the term "atlasing" is used to describe the act of collecting data for such an atlas (Underhill and Gibbons 2002). The essential characteristic of atlas data is that it links records of species presence to exact geographical locations (Harrison 1989). In most cases the data are collected on a grid system, so checklists of species are collected for and referenced to individual grid cells. Various other data may be included, such as temporal and effort data, which allow more detailed and nuanced analyses (Underhill and Gibbons 2002). The first bird atlas was compiled in Britain in 1960 from data collected in 1952, and it used a 50 km grid (Gibbons et al. 2007). The first bird atlas to use a systematic data collection protocol was published in 1970 and covered breeding birds in the west midlands of England. In 1976 that was followed by the first national atlas for Britain, which was on a 10 km grid, and the first continental European atlases (Danish and French) were published in the same year (Gibbons et al. 2007). From then on bird atlas projects began to appear in many parts of the world, using a range of scales and some of them mapping only subsets of the bird species occurring in their region (e.g. only breeding birds, wintering birds or migrating birds). Some atlas projects were repeated after some time had elapsed, but in Gibbons et al.'s (2007) excellent review of bird atlases and the development of atlasing methods, just 12% of the 411 atlas projects they reviewed were repeats. This small proportion may, however, be explained by the relatively short period of time that had elapsed since bird atlasing was first taken up in many of the countries; for example, SABAP2 would not have been included in their dataset because it was only launched in 2007.

In South Africa checklists of birds occurring in defined areas were collected and published from the early 1950s until this type of data collection was superseded by the first systematic atlas projects (Underhill et al. 1991). The initial South African atlas projects were restricted to certain parts of the country; the first to be published was for the former province of Natal (using data collected in 1970–79), followed by a raptor atlas for the former Cape Province (1700–1979), then by atlases of all bird species for the former Transvaal (1960–86), Orange Free State (1983–86) and finally the south-western Cape Province (1982–86) (Underhill et al. 1991). An atlas for Lesotho was published, using data collected in 1986–89 (Underhill et al. 1991). Data collection for the first national bird atlasing project (which also included other countries in southern Africa), SABAP1, began in 1987 and continued until 1992, although it included all compatible data from 1980 onwards; this project is described in detail below.

The overwhelming majority of participants in the type of large-scale bird monitoring programmes discussed above are volunteers – unpaid, amateur bird watchers – as opposed to professional scientists or conservationists. These volunteers, now known as citizen scientists, are indispensible to this type of large-scale bird monitoring, enabling scientists to collect vast quantities of valuable data that it never would have been possible to collect otherwise (Underhill and Gibbons 2002, Greenwood 2007, Cohn 2008, Silvertown 2009, Wright 2011). The citizen science phenomenon has mobilised hundreds of thousands of members of the public, and in becoming part of projects such as these they improve their bird watching skills, increase their education about environmental issues and awareness of the state of the environment in their area, and even become involved in environmental and conservation policy making (McCaffrey 2005, Cohn 2008, Harrison et al. 2008). Modern technology has greatly facilitated citizen science, by increasing the ease with which information can be disseminated to large numbers of people, the ease and convenience with which data can be submitted and the speed with which it can be analysed (Cohn 2008, Silvertown 2009). Using volunteers to collect data involves some compromises in the design of the projects and the types of data that can be collected, however, due to limits on what unpaid volunteers can be expected to do and their likely level of knowledge, but it is generally agreed that these do not outweigh the great mutual benefits involved (Bart 2005, McCaffrey 2005, Greenwood 2007, Cohn 2008).

Several authors have called for monitoring on a continent-wide or global scale, which would enable scientists to monitor biodiversity and ecosystems over a much larger scale than is presently possible (e.g. Bennun 2000, Gregory et al. 2005, Pereira and Cooper 2006). This type of monitoring would involve developing indicator statistics using data from one or two taxa; Gregory et al. (2005) and Bennun (2000) recommend using birds, while Pereira and Cooper (2006) suggest monitoring both birds and plants. The data for individual species would be summarised into one or a few simple statistic(s), as demonstrated by Gregory et al. (2005) for British birds. These statistics would then be used as indicators of the general state or health of the ecosystems in which the birds occur, as has been done with Gregory et al.'s (2005) British birds indices. Some authors have pointed out various problems with using birds as indicators, such as the fact that they appear to be less sensitive to environmental changes than other vertebrate taxa, they are probably only useful as indicators of long-term changes because of their relatively long life spans, and it might be difficult to pinpoint the exact environmental change that has caused a change in population because many different factors affect them (Furness et al. 1993, Pereira and Cooper 2006). However, the comparative ease of identifying and counting birds, the huge numbers of bird watchers who are willing to volunteer their time to contribute to monitoring projects, the large number of such projects that are already underway and the generally advanced state of our knowledge about birds all mean that this is probably the most useful taxon overall to use as an indicator of general environmental change (Furness et al. 1993, Gregory et al. 2005, Pereira and Cooper 2006).

How have monitoring data been used in the past?

Bird monitoring data have been used in a wide range of conservation and scientific applications, and large-scale bird monitoring projects have become an invaluable tool for conservation (Underhill and Gibbons 2002). Monitoring was responsible for the discovery of the now-famous DDT-related decline of Peregrine Falcons *Falco peregrinus*, and for detecting the species' recovery once DDT was no longer being used. It was large-scale citizen science bird monitoring projects that alerted scientists to the dramatic decline in British farmland birds, and monitoring is being used to assess the effectiveness of the conservation measures that have been put in place to reverse that decline (Greenwood 2007). These are just two examples of how long-term bird monitoring have been instrumental in detecting problems and assessing the success of the subsequent management interventions, and there are many more (e.g. Bart 2005).

Bird census data, such as those from the Christmas Bird Counts in the USA and from the Common Birds Census and Breeding Bird Survey in Britain, have been used in scientific studies of population dynamics, community ecology and biogeography (Silvertown 2009). They have also been used to detect distribution changes in response to climate change (National Audubon Society 2009) and in the prioritisation of species and sites in need of conservation, development of land-use practices that protect birds, improving our understanding of the causes of species population change, monitoring environmental change and conservation actions, and in the generation of indicator statistics as discussed above (Underhill and Gibbons 2002, Gregory et al. 2005, McCaffrey 2005). CAR project data have been used to assist in the planning phases of proposed power utility structures, including wind farms and powerlines (Young et al. 2003), and have been used in numerous popular articles and publications aiming to educate land managers about large terrestrial birds and how to conserve them; recently a booklet for farmers containing such information was published which drew on CAR project data (Harrison and Young 2010).

Bird atlas data, including data from SABAP, have been used for even more applications, such as to predict and explain bird distributions; to examine migration phenology, local movements and population sizes; to monitor population trends; for conducting environmental impact assessments; for land-use planning, and the planning of power utility location (Underhill et al. 1991, Underhill et al. 1992, Underhill and Gibbons 2002, Gibbons et al. 2007, Dunn and Weston 2008, Harrison et al. 2008). They have also been used to inform biological survey design and to indentify high priority conservation areas and species in need of conservation, for example areas that will be important to conserve under climate change scenarios, endemic species that are poorly protected, or important areas for British agri-environment schemes aimed at reversing the decline of their farmland birds (Harrison 1989, Dean and Siegfried 1997, Underhill and Gibbons 2002, van Rensburg et al. 2004, Greenwood 2007). Other uses to which atlas data have been put include education and recreation (by producing bird lists for areas that people might visit), and also for taxonomy; for example, an important part of the evidence used to justify splitting the Black Korhaan *Eupodotis afra* into the Northern and Southern Black Korhaans (for more detail see Chapter 3) was their almost completely disjunct ranges, which was discovered upon examining data from SABAP1 (Crowe et al. 1994, Underhill and Gibbons 2002). Some authors have found significant relationships between reporting rates (the proportion of checklists on which a species appears) and population density, and have suggested using reporting rates to calculate bird population sizes, or have used them to compare abundances in different habitats (e.g. Bart and Klosiewski 1989, Robertson et al. 1995, Herremans 1998).

Long-term bird monitoring data used in this thesis

Most of the data collection for the SABAP1 took place from 1987–1992. SABAP2 began in 2007 and is ongoing, and its data can be compared with SABAP1 data (http://sabap2.adu.org.za/). The CAR project started in 1993 has therefore been running for up to 20 years, depending on precinct and species (not all species were included from the beginning; see below). There is a gap of 15 years between the two atlas projects, and therefore a similar time span for both sets of projects over which to detect trends. This represents an opportunity for the comparison of two quite distinct datasets which provide information from two different angles on a number of species of large terrestrial birds.

First and second Southern African Bird Atlas Projects (SABAP 1 & 2)

History

A brief history of the lead-up to the establishment of SABAP1 was given above. A detailed history of SABAP1 itself is given in the Introduction and Methods section of the published atlas (Harrison and Underhill 1997), but a summary is provided here. Unless otherwise stated, the information presented in this section was drawn from Harrison and Underhill (1997) and the SABAP2 project website (http://sabap2.adu.org.za/).

The need for a national, or preferably a subcontinental, atlas was identified at a workshop in 1983, and the idea was further developed at another workshop the following year. In 1986 the steering committee was established, and an Atlas Coordinator was appointed. Regional Atlas Committees (RACs) were established, and bird clubs in Botswana, Lesotho, Namibia, Swaziland and Zimbabwe committed to participation in the project. In 1987 the project was officially launched, and it was extensively publicised in the print media and on television. Within a year the number of volunteers was over 5 000, and after two years it was 6 600. Data from the database were already being requested by researchers in 1989, and the number of requests increased from that point onward. The 12 RACs handled incoming data; the organisation and coordination necessary to deal with the volume of these data were substantial, especially because data were submitted in hardcopy and then had to be computerised. Atlas workshops were held for the RACs, and staff were appointed for the purposes of conducting additional fieldwork in remote areas or designing computer software to deal with the large quantities of data that were being submitted.

At the end of 1991 the main phase of data collection ended, although further data could be submitted for 393 quarter-degree grid cells (QDGCs) until July 1992. Data collection in Botswana and Zimbabwe continued until December 1992, and in Namibia until the end of summer 1993. By 1991 much progress was being made towards publication of the atlas, including the identification of 60 authors for species texts and the development of software for the production of high quality distribution maps. Sophisticated statistical modelling techniques for the analysis of atlas data were also developed. Various complications such as delays in the arrival of some data, and extensive text editing and data vetting requirements delayed publication of the atlas until 1997, but when it was published it was recognised as "the biggest biodiversity research project in Africa, ever" and the database it produced as "amongst the largest of its kind in the world" (p xxvii, Harrison et al. 1997). The complete dataset contained 147 605 checklists, including 7 332 504 individual records. The depth of coverage (number of checklists submitted) for each QDGC was not uniform, but all of South Africa's QDGCs except one were visited at least once (Figure 3a).

SABAP1 was not intended to be the definitive source of bird distribution information, to be used for posterity and to set bird distributions in stone. Rather, it was envisaged as providing a snapshot picture of bird distributions as they were in the late 1980s and early 1990s, and from the outset it was hoped that it would be followed by a repeat atlas before too much time had elapsed. In mid-2007 this vision was realised with the launching of SABAP2. The protocol changed somewhat, increasing both the spatial and the temporal resolution and adding effort data to the data collection protocol (see below). However, the new protocol was designed with comparison of the two datasets in mind, and in this thesis I explore two ways in which that can be done. The history of SABAP2 thus far has yet to be published, but much information about the project can be obtained from the project website (http://sabap2.adu.org.za/) and a useful summary of the aims of SABAP2 and the changes to the protocol can be found on the old project website, and is still available at http://sabap2.adu.org.za/v1/about.php.

Methodology of SABAP 1 & 2

The protocol used for SABAP1 is described in detail in Harrison and Underhill 1997, and for SABAP2 on the project's website (http://sabap2.adu.org.za/), but a summary is provided here for ease of reference. Unless otherwise stated, the information presented in this section is drawn from the above two sources.

In both atlas projects participants recorded the presence of all bird species they observed within a grid cell within a set period of time. Grid cells were demarcated by lines of longitude and latitude. The protocol was simpler for SABAP1 than for SABAP2, and the key differences between the two projects were:

- the grid cells used were QDGCs, i.e. 15' by 15', for SABAP1, and "pentads", defined as 5' by 5', for SABAP2 (there were thus nine pentads in every QDGC);
- the time period over which a list could be collected was 30 days for SABAP1 and only 5 days for SABAP2;
- for SABAP2 observers were required to spend a minimum of two hours in the pentad for each checklist submitted, and to cover all habitats in the pentad if possible; no such requirements existed in SABAP1 (however, SABAP2 observers could submit *ad hoc* lists and incidental records, because these data were considered useful even if they could not be included in analyses requiring full protocol lists);
- observers recorded species in the order in which they were seen in SABAP2, together with the cumulative total number of species seen by the end of each hour, the total amount of time spent atlasing per list, and other effort and observer related data; there were no such requirements in SABAP1.

These differences present various challenges for the data analysis, which are examined in the individual chapters as appropriate. However, the average checklist lengths for both projects were similar: 50 and 53 species for SABAP1 and SABAP2 respectively. The implication of this is that the average reporting rates across all species are nearly the same between projects. If they were not the same, then it would have been appropriate to develop a factor to adjust the reporting rates. This was deemed unnecessary.

The accuracy of data accepted into the databases of both atlas projects was of paramount importance. Vetting of data for SABAP1 was conducted by the RACs and the final editing team. For SABAP2 much of the initial data checking was done automatically by the computer software as data were submitted, by checking records against previous records for the same species in the vicinity of the pentad in question. Where a species was reported far outside its previous accepted range, a request for further information (known as an Out-of-Range Form) was sent to the observer. This form, once completed, was sent to the relevant RAC for vetting. A National Rarities Committee was set up for adjudicating records that the RAC could not.

Status as of January 2012

Most analyses using SABAP2 data presented in this thesis include all full protocol data submitted up until the end of January 2012, hence I report on the status of coverage as it stood on 31 January 2012.

Probably mostly because of the more stringent data collection protocol, as well as the relatively greater costs of participation (especially higher fuel prices), progress on SABAP2 was slower than it was for SABAP1, but nevertheless after 4.5 years of operation, 86% of QDGCs had SABAP2 data submitted (SABAP2, unpubl. data). The total number of registered observers was 1 009, and the number of checklists submitted was 65 087, including 3 466 460 individual records. Checklists had been submitted for a total of 10 114 pentads, 58% of all pentads in South Africa (Figure 3b). A further 260 960 incidental records had been submitted. These figures are continuously updated on the project's website (http://sabap2.adu.org.za/).

Derived reporting rate range maps

Range maps produced using both SABAP1 and SABAP2 data, termed derived reporting rate maps, are presented for each of the six species for which I conduct detailed analyses (Chapters 3–6). Some explanation of the method used to produce these maps and the interpretation thereof is necessary here, to avoid repetition in those chapters. The Blue Crane derived reporting rate map is given here as an example (Figure 4).

Reporting rates, defined as the proportion of checklists for a grid cell which report the presence of the species in question, were calculated using both SABAP1 and SABAP2 data. SABAP2 pentad data were assigned to the QDGC in which the pentad was located. Derived reporting rates were calculated as follows

where R_D is the derived reporting rate, R_1 and R_2 are the reporting rates for SABAP1 and SABAP2 respectively, and x is the number of SABAP2 checklists submitted for that QDGC by the date on which the map was created. Therefore, if 25 or more SABAP2 checklists had been submitted for a QDGC by the date on which the map was extracted, the reporting rate for that QDGC was calculated using only SABAP2 data. If no SABAP2 checklists had yet been submitted for a QDGC, SABAP1 data only would be used. If one to 24 SABAP2 checklists had been submitted, the reporting rate was calculated using data from both projects, with the contribution from each project weighted according to the number of SABAP2 checklists submitted, with SABAP2 reporting rates receiving a larger weight if more checklists had been submitted, as shown in the formula above. The choice of the value of 25 was based on experience; other choices were explored. It was found, however, that reporting rates for a QDGC tended to stabilise when c. 25 check lists had been submitted from pentads within that grid cell. Reporting rates based on 25 SABAP2 check lists were therefore taken as sufficiently reliable to use on their own, without incorporating SABAP1 reporting rates.

In the maps QDGCs were colour-coded according to six categories. The cut-points for the categories were determined by dividing the reporting rates for all QDGCs with non-zero reporting rates into six equal-sized groups, i.e. quantiles. Thus as close as possible, 16.7% of cells were shaded in each colour category on the map. Departures from this were caused when cells with identical reporting rates fell on the cut-points for the categories. The dark blue areas of the map should be interpreted as the core areas of the range, because these are where the reporting rates were highest (the top one-third of reporting rates), and the yellow and orange QDGCs generally represent the edges of the range and possibly some vagrant records (the bottom one-third of reporting rates).

Coordinated Avifaunal Roadcounts (CAR) project

History

A detailed history of the project up to 2003 was provided in Young et al. (2003), and in unpublished annual reports compiled by the Project Coordinator (currently Mrs Donella Young of the ADU). A summary is provided here, because it represents important background information to this thesis. Unless otherwise stated, the information presented in this section was drawn from Young et al. (2003).

The CAR project was initiated by David Allan in 1993, based on methods he had used to assess the abundance and distributions of Blue Cranes and Denham's and Ludwig's Bustards for his MSc project (Allan 1993). The principle aim of the project was to monitor populations of large terrestrial birds in agricultural areas, because these are the areas they depend upon for their survival, and formal protected areas are not sufficient to conserve these species. The project began in the Overberg region of the Western Cape in July 1993, and initially focused only on Blue Cranes and Denham's Bustards. In 1995, once the reliability and usefulness of the data had been established, the project began to expand to include other species and areas. The first new areas to be included were the Swartland region of the Western Cape and the Eastern Karoo precinct[2] in the Northern Cape, both of which started in 1995. In the Eastern Karoo precinct all storks, Ludwig's and Kori Bustards, Secretarybirds and Karoo Korhaans were counted, and in the Western Cape precincts the Secretarybird and the White Stork were added to the list of target species.

In 1997 the total distance covered doubled (from 4 545 km to 9 066 km) as the project expanded to include parts of the Free State and KwaZulu-Natal, and the list of target species grew to include the other two large bustards, the other two cranes, all storks, Black-headed Herons, Spur-winged Geese and Southern Ground-Hornbills *Bucorvus leadbeateri*. Other species were added on a precinct-by-precinct basis from then on. In 1998 counts began in the Eastern Cape and Mpumalanga provinces, and already-established precincts continued to expand, so that in the winter count of that year 225 routes, covering 14 450 km, were surveyed. By winter 1998 the Southern Bald Ibis and all korhaans had been included, as well as gamebirds in KwaZulu-Natal. In 2000 the project stabilised, with 302 routes covering 18 300 km of roads and involving about 700 participants. By then there were three large precincts in the Free State, three precincts in each of Mpumalanga, KwaZulu-Natal and the Eastern Cape, and an additional two precincts had been added in the Western Cape. In 2004 a precinct in Gauteng was started, and most of the routes in that precinct were established by 2006.

The project fluctuated in size slightly over the following decade, and a small number of new species was added to the list, so that in 2011 a total of 36 bird species (and one small antelope) was surveyed (http://car.adu.org.za/index.php). A small proportion of routes had to be altered or discontinued for various reasons, such as sections of the road deteriorating so that they became impassable in wet weather, or sections of the route becoming unsuitable for birds due to changing land-use, for example afforestation, mining or increasing human population density. Although this latter reason biases monitoring results, it is a reality of a project that makes use of volunteers. If less than 10% of the route was impacted by these changes, the project policy was to retain the same code for the route, but if the change was greater than this it was assigned a new code. This was done so as not to violate the assumption inherent in most analyses of these data that the area sampled each year was the same as in other years.

[2] The use of the term "precinct" is given two meanings in Young et al. (2003), where it is used to refer to both the original groupings of routes that were administered by local bird clubs or CAR participants, and to the larger ecological precincts, defined primarily on the basis of natural vegetation type, but also taking topography and bird distribution into account. Throughout this thesis I use the term to refer to the larger, ecologically-defined precincts.

Methodology

The methodology of the CAR project is described in detail in Young et al. (2003). A summary is provided here for ease of reference. Details of methods can also be found in the information sheets on the project's website (http://car.adu.org.za/index.php). Unless otherwise stated, the information presented in this section was drawn from Young et al. (2003).

CAR surveys were carried out twice a year by volunteers across a large portion of South Africa. The majority of the volunteers were amateur bird-watchers, many of whom were local farmers. The summer count was conducted on the last Saturday of January each year, and the winter count on the last Saturday of July. Surveys were carried out at the same time and on the same day in order to minimise the possibility of double-counting individual birds. Routes were fixed and had been digitised in ArcView 3.1 (Environmental Systems Research Institute Inc. 1998), a geographical information system (GIS) programme. Routes were laid out such that there was never less than 2 km between two routes or between two sections of one route (e.g. if a route was circular, the end of the route was at least 2 km away from the start). This further decreased the risk of double-counting individuals. The average length of the routes was c. 60 km.

Routes were selected to ensure that coverage of each precinct was as complete as possible. Route selection was necessarily, however, also determined by the availability of suitable roads, as well as volunteers who were willing and able to survey those roads. One inherent bias in the selection of routes was dictated by the vagaries of a project involving volunteers. The willingness of volunteers to survey routes on which few or no birds are seen is understandably limited. Thus some routes traversing areas in which large terrestrial birds became scarce, for example where forestry plantations or mining operations were established after the CAR project began, were discontinued. Where these activities were already established prior to the CAR project, routes tended to avoid these areas. The selection of routes was therefore not random, but a concerted effort was made to ensure a representative coverage of *agricultural* habitats within each precinct. This may have had the effect of biasing the results somewhat, inasmuch as some non-agricultural habitats may have been under-represented. However, coverage of agricultural habitats was as complete as possible, and because so large an area was covered in each precinct it is likely that any small biases caused by individual route selection were, in general, removed when the data for all the routes of each precinct were pooled.

The survey protocol was clearly laid out and explained to all participants. Each vehicle should ideally have at least two people in it. There was no upper limit set to the number of people allowed to survey one route, but in most cases one vehicle, containing two to four people, surveyed each route (if more than one vehicle surveyed one route, they travelled together). Vehicles travelled no faster than 50 km/h for the duration of the survey, and stopped every 2 km. At these points the participants disembarked and scanned the surrounding area carefully with binoculars, and counted any individuals of the target species that they saw (or heard calling, in the case of the korhaans). They also stopped whenever they saw any of the target species, even if they were between their 2 km stops, and repeated this procedure. The use of telescopes to aid identification was encouraged.

The numbers of birds of each of the target species seen at each stop was recorded, as well as the distance from the starting point of the route (to 0.1 km) using the vehicle's trip-meter (the trip-meter was set to zero at the starting point). The total length of the route, according to the vehicle's trip-meter, was also recorded. This allowed for accurate digitisation of all sightings, because although the accuracy of individual trip-meters varied greatly, when the recorded total route length was related to the known actual route length as calculated in the GIS, the distances recorded for all the sightings on that route could be adjusted accordingly, and the sightings could then be georeferenced and plotted. The reference point was the position of the observer along the road, rather than the position of the bird. Thus most positions are accurate to within a kilometre.

The birds seen were classified according to easily identifiable age categories (adult, juvenile or chick), and the habitat in which they were seen, together with any relevant nearby features (e.g. waterbodies, feeding troughs, etc.) were recorded. For cranes and the three large bustards, their activity and the side of the road on which they were seen were also recorded. Finally, for the whole count, the weather and visibility conditions on the day were noted, as well as any other factors that may have affected the count.

Status as of December 2010

In 2010 (the last year from which data are included in this thesis), 303 routes were surveyed in summer and 311 in winter[3], covering c. 18 000 km of roads in 19 precincts

[3] In the Eastern Karoo precinct each route was divided into three 20 km sections separated by a few kilometers from each other. Each of these sections was given a separate code in the database and was therefore treated as a route in its own right. For uniformity I have treated each of these sets of three short routes as one 60 km route for the purposes of calculating summary information such as average route length and the number of routes surveyed.

(Figure 1; CAR project, unpubl. data). Each six-monthly survey involved c. 700 volunteers and the project covered a large proportion of the agricultural areas in the south-eastern half of South Africa.

CAR precincts

By 2010 the CAR project operated in 19 precincts (Figure 1). In this thesis I use data from 18 of these; the 19th, Wilderness, consisted only of two routes and had not yet been surveyed enough times by 2010 to use in any of my analyses. In this section I describe briefly the 18 precincts from which I did use data. This information is consolidated here so that it is available at a single point in the thesis, rather than scattered through the chapters. This section draws largely from Young et al. (2003) and the CAR database (CAR project, unpubl. data). The number of routes I give for each precinct is the total number of all the routes ever surveyed in the precinct, and in some cases includes routes that by 2010 were no longer active or had been altered by more than 10% and therefore renamed. Routes average 60 km in length, and represent one of the basic units of analysis in this thesis. Species recorded are generally listed in descending order of abundance in that precinct.

Eastern Cape Coastal

The Eastern Cape Coastal precinct was established in 1998, and in 2010 there were 11 routes in the precinct; four of these had not been surveyed enough times to be included in the population trend analyses. The precinct consists of two separate groups of routes, one in the west near Humansdorp, and one in the east near Kenton on Sea.

This precinct consists of a range of undulating landscapes, from rolling coastal plains to low mountains. The natural vegetation is varied, because six of South Africa's nine biomes meet in this precinct. In the western group of routes the Fynbos, Albany Thicket and Forest biomes are all represented, while in the eastern group Savanna, Albany Thicket, Nama Karoo and Grassland meet. A wide range of agricultural activities occur in this precinct, including livestock (sheep, cattle, ostriches, goats) farming, the cultivation of various cereals, orchards and the growing of cash crops such as chicory and tobacco.

Large terrestrial birds are abundant in this precinct, and large densities of Denham's Bustards, Blue Cranes, White Storks, Spur-winged Geese and Black-headed Herons are recorded. Other species seen include White-bellied Korhaans, Secretarybirds and the occasional Southern Black Korhaan.

Eastern Cape Karoo

CAR counts began in the Eastern Cape Karoo precinct in 1998. In 2010 there were 28 routes in this precinct; eight of these had not been surveyed enough times to be included in the population trend analyses.

The routes of this precinct traverse plains between small mountain ranges, and are well spread out across much of the western half of the Eastern Cape, bounded by the Baviaanskloof mountains in the south. The primary natural vegetation is Nama Karoo, although it varies substantially with rainfall. MAR is c. 250 mm in the west of the precinct, rising to 400–450 mm in the east, although it is everywhere variable, and extended droughts are regular occurrences. When and where there is more rain, grasses become established, but when and where it is drier, karoo shrubs dominate, so in some areas the natural vegetation fluctuates between Nama Karoo and grassland. The main land-use in this precinct is livestock farming, primarily of sheep, goats and ostriches, but also of cattle where the vegetation has a larger grass component. A relatively recent addition to the list is game farming, and along watercourses there are irrigated fields of wheat, lucerne and maize.

Large terrestrial birds are generally reasonably scarce in the Eastern Cape Karoo precinct, except for White Storks, which are abundant in summer. The next most abundant species was the Blue Crane, and other species recorded include Southern Black Korhaan, Northern Black Korhaan, Karoo Korhaan, Ludwig's Bustard, Kori Bustard, Denham's Bustard, and more.

North-eastern Eastern Cape

This precinct was established in 1998. By 2010 there were 31 routes; 11 of these had not been surveyed sufficient times to be included in population trend analyses.

The routes in the North-eastern Eastern Cape precinct are all situated or next to mountain ranges of various sizes. The topography of the precinct ranges from undulating to steep and rugged, and the natural vegetation is mainly Grassland, with small patches of Albany Thicket and Forest in the south. The main land-use practised in this precinct is livestock (cattle and sheep) grazing, with some crop and forage cultivation on floodplains; however, there is also some afforestation in the north-east of the precinct.

A relatively large number of large terrestrial bird species is recorded in this precinct, and it is an especially important area for Grey Crowned Cranes and Blue

Korhaans. Other species recorded here include White Storks, Spur-winged Geese, Black-headed Herons, Blue Cranes, Denham's Bustards, Secretarybirds and more.

North-eastern Free State

CAR counts began in the North-eastern Free State precinct in 1997. In 2010 there were 62 routes in total; 29 of these had been surveyed enough times to be included in the population trend analysis.

The topography of this precinct is mainly rolling hills with several large koppies and many rivers in the higher altitude east and south, with flatter, lower altitude land in the north and north-west. The natural vegetation of the precinct consists almost entirely of Grassland, with small patches of trees and shrubs, and even a little Forest, on the slopes of the mesas. Along the eastern border there are some important high-altitude wetlands. Approximately two thirds of the precinct are devoted to livestock (cattle and sheep) grazing, and most of the remaining third is used for dryland cultivation. Crops grown include wheat, maize, pastures and hay.

Large terrestrial birds occur at relatively low densities in this precinct, but this is the precinct with the highest densities of Southern Bald Ibises. Other species recorded include Spur-winged Geese, White Storks, Black-headed Herons, Blue Cranes, Grey Crowned Cranes, Blue Korhaans, Secretarybirds, Northern Black Korhaans and others.

North-western Free State

This precinct began operation in 1999. In 2010 there were 48 routes in the precinct; 21 had been surveyed enough times to be included in the population trend analysis.

Most of the North-western Free State precinct is very flat, although there is a region of low rolling hills in the north of the area. In the south-west there is an area with scattered ephemeral water pans. This precinct falls almost entirely within the Grassland biome, with a small area of Savanna in the hilly area in the north and along the Vaal River, which forms the north-western boundary of the precinct. Slightly more than half of the precinct is cultivated, with maize, sorghum, wheat and pastures being the most common crops (in descending order of importance). Most of the remainder of the area is used for livestock (primarily cattle) grazing in natural veld.

Large terrestrial birds, once common and diverse in this precinct, are now generally scarce, and the only species that remains in large numbers is the Northern Black Korhaan. Other species which are recorded include Spur-winged Geese, Black-headed Herons, White Storks, Blue Cranes, Blue Korhaans and more, although most of these are seen in far lower numbers than was historically the case, and some species, such as Grey Crowned and Wattled Cranes, have disappeared entirely from the area.

Southern Free State

CAR counts began in the Southern Free State precinct in 1997. This is by far the largest precinct, both in terms of area and the number of routes surveyed. In 2010 there were 126 routes in total; 78 had been surveyed enough times to be included in the population trend analysis.

This precinct occupies much of the southern half of the Free State, and consists of flat to gently rolling plains with scattered koppies. The topography is more hilly and there are more koppies in the south-east than in the north-west of the precinct, where there are numerous ephemeral water pans. Although in Young et al. (2003) the precinct is described as mostly within the Nama Karoo biome, Mucina and Rutherford (2006) classify most of the area covered by this precinct as Grassland (Figure 2). This probably reflects the difficulty of drawing biome boundaries where a wide ecotone between two biomes exists, as it does in this precinct; much of it is grassy karoo, ranging from pure Grassland in the wetter east and north-east to pure Nama Karoo in the drier western corner of the precinct. Trees and shrubs are restricted to rocky slopes and watercourses. The great majority of the farming in this precinct is livestock (mainly sheep and cattle) grazing on natural veld, but a small proportion of the land is used for cultivation of crops such as wheat, maize and sunflowers.

A wide range of large terrestrial birds occurs in this precinct, including large numbers of Northern Black and Blue Korhaans, Blue Cranes and Ludwig's Bustards. Abdim's and White Storks are periodically recorded in large numbers here, and Spur-winged Geese, Black-headed Herons and Secretarybirds are also relatively common.

Gauteng

This precinct started in 2004 and was therefore not discussed in Young et al. (2003). In 2010 there were 26 routes in the precinct, one of which had been surveyed only three times. The precinct had not been running long enough to include any data in the population trend analyses, but some data from the precinct were used to describe habitat use.

Much of the topography is rolling hills with some rocky outcrops, and more hills and mountainous terrain in the north-west of the precinct, where it is bounded by the Magaliesberg range. Natural vegetation in this precinct is a mixture of the Grassland

and Savanna biomes, with a greater percentage of the precinct in the Grassland biome (Mucina and Rutherford 2006). Approximately 50% of the province, mainly in the centre, is occupied by the cities of Johannesburg and Pretoria (Hoffmann and Ashwell 2000), thus the CAR routes are spread around the edges of the province (Figure 1). Close to half of the land visible from the CAR routes is cultivated (SANBI 2009), and the most important crops grown on this land are maize, sorghum, sunflowers, beans and deciduous fruit (Hoffmann and Ashwell 2000). Most of the rest of the land is used for livestock (cattle and sheep) grazing.

There is a relatively wide diversity of large terrestrial birds in this precinct, although most species are seen in small numbers. The most abundant species are Helmeted Guineafowls, Black-headed Herons, Spur-winged Geese, Northern Black Korhaans, White Storks and Blue Cranes. Other species recorded in the precinct include Secretarybirds, Southern Bald Ibises, Blue Korhaans, White-bellied Korhaans and others.

Northern KwaZulu-Natal

CAR counts began in the Northern KwaZulu-Natal precinct in 1997. In 2010 there were 23 routes in this precinct, of which two had not been surveyed sufficient times to be included in the population trend analysis.

The topography of the precinct consists mainly of extensive plains, although two small mountain ranges run through the area. The natural vegetation is Grassland, but there are now areas of bush encroachment (where Savanna bushveld encroaches into Grassland because of overgrazing). The MAR in the precinct is reasonably high and fairly uniform across the area, ranging from 850 mm to 900 mm. There are several large wetlands in the precinct, but some of them have been negatively affected by drainage canals. The majority of the area is used for livestock farming, mainly cattle grazing on natural veld, but with some planted pastures. Some crops are cultivated, such as maize, wheat, sorghum, soya and sunflowers, and there is afforestation in a small proportion of the area.

There is a high diversity of large terrestrial birds in this precinct, although most of them occur at small densities. Species recorded in the precinct include Southern Bald Ibises, Grey Crowned Cranes, White-bellied Korhaans, Denham's Bustards, Blue Cranes, Secretarybirds, White-bellied Korhaans, Blue Korhaans and more. The most abundant CAR species in the precinct are Spur-winged Geese, Helmeted Guineafowls and White Storks.

Southern KwaZulu-Natal

In 2010 the Southern KwaZulu-Natal precinct comprised 23 routes; three had not been surveyed sufficient times to be included in the population trend analysis. Surveys began in this precinct in 1997.

The topography in this precinct consists of rolling hills; in the west the precinct is bounded by the Drakensberg mountains, and the north-western-most routes are in the foothills of this range. The north of the precinct receives more than 1 000 mm of rain per year, while in the south the MAR is c. 800 mm. Two large rivers meander through the precinct, and poor drainage in the floodplains has resulted in extensive seasonal wetlands. The vegetation is primarily Grassland, with some small areas of Forest and Savanna, including both sparse and dense woodland. A large proportion of the grassland has been transformed; predominant land-uses are afforestation, livestock (mainly cattle) grazing on planted, irrigated pastures, maize and potato cultivation, and some livestock grazing on natural veld. Many of the rivers have been dammed for irrigation and for recreational purposes (mainly fishing), and this has affected many of the wetlands negatively. Tourism is now an important source of income in the area, with trout fishing being one of the principal attractions. There are, however, several nature reserves in the precinct.

This is an important precinct for Wattled and Grey Crowned Cranes, as well as Helmeted Guineafowls, Black-headed Herons and Southern Bald Ibises. Blue Cranes, Denham's Bustards, Southern Ground-Hornbills and Secretarybirds also occur here in smaller numbers, and the most numerous species recorded are White Storks and Spur-winged Geese.

Western KwaZulu-Natal

This precinct was established in 1997. In 2010 there were 16 routes in this precinct; seven had not been surveyed sufficient times to be included in the population trend analysis.

The terrain in the Western KwaZulu-Natal precinct (referred to as Mid-western KwaZulu-Natal in Young et al., 2003) ranges from rolling hills to mountainous, and there is a wide range of altitudes, from 650 m ASL in the east to c. 2 000 m ASL in the high foothills of the Drakensberg in the west. Vegetation and rainfall vary with the terrain, from the hot, dry east, which receives 600 mm of rain per year and is characterised by dense Savanna vegetation, to the cool, high altitude west, which receives 1 400 mm of rain annually. Most of the precinct's natural vegetation is Grassland. A range of agricultural activities take place in this precinct, including livestock farming (mainly cattle, grazed on both natural veld and planted pastures), cultivation of maize, wheat, soya, vegetables and citrus, and there is some afforestation in the higher altitude areas. There is also game farming in the east, and much of the Drakensberg area is conserved.

Large terrestrial birds generally occur in low densities in this precinct; Blue and Grey Crowned Cranes occur in relatively low numbers, but it is an important area for Southern Bald Ibises and White-bellied Korhaans. Helmeted Guineafowls are seen in large numbers, and White Storks and Black-headed Herons are the next most abundant species. Among the other species seen in low numbers are Denham's Bustards and Blue Korhaans.

Mpumalanga

Routes in the Mpumalanga precinct as defined in Young et al. (2003) were separated into two smaller precincts, Steenkampsberg and Mpumalanga, following a suggestion from the CAR Project Coordinator and advice from several individuals who know the area well (D Harebottle, W Tarboton and DJ Young pers. comms). This was done because of the altitude difference between the Steenkampsberg routes (coded MS) and the other Mpumalanga routes (MC, MM and MT); the Steenkampsberg area is considerably higher and more mountainous than the rest of the area. In 2010 there were 15 routes in total in the Mpumalanga precinct as defined here; four of these had not been surveyed enough times to include in the population trend analyses. The precinct began operations in 1998.

This precinct has grown substantially since the publication of the 2001 report (Young et al. 2003), and in 2010 covered much of the land between the Wakkerstroom and Steenkampsberg precincts, and some land to the north-west of the Wakkerstroom precinct. It consists primarily of rolling grasslands with many watercourses and wetlands. The natural vegetation is Grassland. Approximately half of the area is intensively cultivated (SANBI 2009), and important crops in the region include maize, potatoes and sunflowers. Most of the remaining natural vegetation is used for livestock (cattle and sheep) grazing. There is some afforestation in the east of the precinct, and there is opencast coal mining in several areas.

Large terrestrial birds are relatively diverse in this precinct, and species seen include Helmeted Guineafowls, Spur-winged Geese, White Storks, Black-headed

Herons, Southern Bald Ibises, Blue Cranes, Blue Korhaans, Grey Crowned Cranes, Northern Black Korhaans, Secretarybirds, a small number of Denham's Bustards, and more.

Steenkampsberg (Mpumalanga)

This precinct was established in 1998, and in 2010 there were 12 routes; three had not been surveyed enough times to be included in the population trend analyses.

The precinct includes the Steenkampsberg Plateau and surrounding highland areas, and the topography is primarily rolling hills between 1 500 m and 2 400 m ASL. However, it is bounded in the north, east and west by more mountainous terrain characterised by steep slopes and ravines. The natural vegetation in this precinct is Grassland, including much wetland. The majority of the precinct is used for livestock (mainly cattle) and game farming, on natural veld. Many of the rivers have been dammed for trout fishing, and many wetlands have been irrevocably damaged. There is a small amount of cultivation (mainly maize and pastures), and some scattered afforestation.

Large terrestrial birds recorded in this precinct include Helmeted Guineafowls, Southern Bald Ibises, Spur-winged Geese, White Storks, Black-headed Herons, Grey Crowned Cranes, Blue Cranes, Secretarybirds, Denham's Bustards, a small number of Wattled Cranes, and more.

Wakkerstroom (Mpumalanga)

The Wakkerstroom precinct was established in 2000. In 2010 there was a total of 10 routes in the precinct.

This precinct is bounded in the south by the borders of KwaZulu-Natal and the Free State. The altitude ranges between 1 500 m and 2 200 m ASL, and rainfall is generally plentiful, with MAR figures between 800 mm and 1 400 mm. The topography consists of rolling hills in the west and mountainous terrain in the east, where the precinct passes over the Great Escarpment. This precinct lies entirely within the Grassland biome, but on some slopes there are patches of Ouhout *Leucosidea sericea*, which is a short to medium height bushy tree. There are many wetlands and some farm dams in the west. The principal land-use in this area is livestock (sheep and cattle) grazing in natural veld. The growing season is too short for most cultivation, but there has been interest in both afforestation and mining in this region, both of which have been strongly resisted by the conservation community, so far successfully, because of the high conservation value of the region.

There is a wide diversity of large terrestrial birds, especially bustards and cranes, in this precinct, although many of them occur in relatively low numbers. Species recorded include White Storks, Southern Bald Ibises, Spur-winged Geese, Black-headed Herons, Blue Korhaans, Secretarybirds, Grey Crowned and Blue Cranes, Denham's Bustards, White-bellied Korhaans and Black-bellied Bustards.

Eastern Karoo (Northern Cape)

This precinct was established in 1995. In 2010 there were 38 routes in total in the Eastern Karoo precinct, of which 22 had been surveyed sufficient times to be included in the population trend analyses (see footnote 3).

This precinct consists of mostly flat to gently undulating plains, with scattered koppies and small mountain ranges. The natural vegetation is grassy Nama Karoo, and the erratic rainfall averages between 300 mm and 400 mm per year. The quantity of rainfall received in a year and grazing pressure both affect how grassy the vegetation is. Almost all the farming activity in the area is small livestock (mainly sheep) farming, with most of the sheep grazing on natural veld. There is an increasing number of game farms, however, and a small proportion of the land is devoted to lucerne or prickly pear cultivation.

The diversity of large terrestrial birds in this precinct is high, with relatively large densities of Blue Cranes, Ludwig's Bustards and Northern Black Korhaans, and Karoo and Blue Korhaans also being recorded. White Storks are by far the most abundant species in summer.

Beaufort West (Western Cape)

The Beaufort West precinct is small, comprising only three routes, one of which had only surveyed three times in total by 2010. Surveys of this precinct began in 1999.

This precinct is situated in the Great Karoo, within the Nama Karoo biome. Typical karoo scrub vegetation is dominant in the flat areas, and there is some grass around natural springs and the rocky outcrops and small mountains spread across the plain. The principal type of farming practised in this region is sheep farming, and the sheep mainly graze natural veld. There is some game farming as well, and some farms have lucerne fields and occasionally olive groves. Periodic locust outbreaks are generally dealt with by spraying poison, although not all farmers permit this to be done on their land.

Large terrestrial birds are generally scarce in this precinct, except for the Karoo Korhaan, which is abundant here. Small numbers of Blue Cranes, Kori Bustards, Ludwig's Bustards, Northern and Southern Black Korhaans and Secretarybirds are seen.

Little Karoo (Western Cape)

For this thesis the Little Karoo and Uniondale precincts in Young et al. (2003) have been joined, because they were considered ecologically similar enough to be treated as one precinct. This also facilitated more meaningful data analysis, because taken separately each precinct consisted of a small number of routes. In this thesis they are jointly referred to as the Little Karoo precinct. The first surveys in this precinct took place in 2000. In 2010 there were 14 routes in this precinct; seven had not been surveyed enough times to include in the population trend analyses.

The terrain in the Little Karoo precinct is mainly rolling hills, bounded by mountains. The natural vegetation consists of a mixture of Succulent Karoo and renosterveld Fynbos vegetation. The main agricultural activities in the precinct are livestock (cattle, sheep and ostriches) farming, cereal crop (mainly wheat) cultivation and onion seed production. There are irrigated orchards and vineyards along river courses.

Large terrestrial birds recorded in this precinct include Blue Cranes, Denham's Bustards, Karoo Korhaans, White Storks, Southern Black Korhaans and Spur-winged Geese and more.

Overberg (Western Cape)

The Overberg is the longest-running precinct, having been established in winter 1993. In 2010 there were 36 routes; three had not been surveyed enough times to be used in my population trend analyses. The route WK02, originally part of the Little Karoo precinct, was included in my Overberg analyses, as suggested in Young et al. (2003).

This is the most southerly of the CAR precincts, and one route comes within a few kilometres of Cape Agulhas, the southernmost point on the African continent. It is primarily a coastal plain and consists mainly of rolling hills, bounded in the north by mountains and in the south by the Indian Ocean. The precinct is within the Fynbos biome, and the natural vegetation is largely renosterveld, with other types of Fynbos vegetation on specific soils. Almost all of the original renosterveld has been ploughed up for agriculture, however, and less than 5% of it remains. The main agricultural activities in this precinct are cereal crop cultivation, mainly wheat and barley, combined with pastures on which sheep, cattle and ostriches are grazed. Non-cereal crops such as canola are also cultivated, and there are some vineyards and orchards.

Large terrestrial birds occur in great abundance in this precinct; species regularly recorded include Blue Cranes, Denham's Bustards, Southern Black Korhaans, Karoo Korhaans, Black-headed Herons, Spur-winged Geese, White Storks, Secretarybirds and more.

Swartland (Western Cape)

Counts began in the Swartland precinct in 1995; it was the second precinct to be established in the Western Cape. In 2010 there were 17 routes in the Swartland; one had only begun operating that year.

The Swartland is an area of rolling hills punctuated by isolated small mountains of various sizes, and bounded by mountains in the east and the Atlantic Ocean in the west. Its natural vegetation comprises various types of Fynbos, including renosterveld, but a large proportion of this vegetation (especially the renosterveld) has been converted to agriculture. It is a primarily wheat-growing area, but incorporating pastures and livestock farming and, to an increasing extent, vineyards.

Large terrestrial birds are generally relatively scarce in this precinct, although Blue Crane populations increased greatly since the beginning of the project (Chapter 4), and the reverse is true for Southern Black Korhaans (Chapter 3).

Environmental change in South Africa

Environmental change includes any large-scale change in the environment and encompasses anthropogenic climate change and land transformation, as well as non-anthropogenic ("natural") change. In this thesis I focus on anthropogenic change, and primarily land transformation, because climate change and its impacts in South Africa are as yet largely conjectural. However, there is little doubt that climate change will have a substantial effect on ecosystems in this country, including natural biota and anthropogenically altered systems. Several, if not all, of the bird species I focus on are likely to be negatively affected by climate change, so I briefly discuss both land transformation and climate change predictions for South Africa below.

Land transformation

The National Land-Cover map for South Africa for 2009 indicates that a total of 15.7% of the country has been transformed (Figure 5a) (Schoeman et al. 2010). This breaks down into 2.0% urbanisation, 1.6% afforestation, 0.2% mining and quarries, and 11.9% cultivated (Figure 5b). The remaining 84.2% comprises natural vegetation and waterbodies. However, in 1989 it was estimated that at least 83% of South Africa's land surface was farmland, and a further c. 10% transformed in other ways, leaving only c. 7% of the country as natural, undisturbed vegetation (Macdonald 1989). The National Land-Cover maps unfortunately do not discriminate between fully natural vegetation and vegetation that has been grazed by livestock, so it is not possible to calculate the total percentage of the land that is farmed using these maps (Thompson 1999, CSIR and ARC 2005, SANBI 2009). However, this is an important distinction for birds and other organisms that depend on natural vegetation, and I discuss it further here. The availability of land-use data also presented some difficulties for my habitat selection analyses (Chapters 3–6), and these are also discussed here.

The habitat selection analyses presented in this thesis required a source of habitat availability data, since CAR participants recorded habitat only where birds were seen and not for the whole route. The only available data sources that covered both the entire study area and study period were the National Land-Cover (NLC) maps of 1994, 2000 and 2009 (Thompson 1999, CSIR and ARC 2005, SANBI 2009). These maps were produced using mainly satellite imagery and were intended to present an overall picture of land cover at the time the imagery was produced. They could not, therefore, discriminate between many of the seasonal habitat types relevant to large terrestrial birds, such as crop fields (and types of crops), stubble fields, fallow land, burnt land, mowed land and ploughed land. Similarly, CAR participants did not discriminate between agricultural habitats in the same way as the NLC1994 and NLC2000 maps do, with categories such as "permanent irrigated cultivated commercial agriculture" and "temporary dryland subsistence agriculture" and many other variants on these. The NLC2009 map has far fewer habitat categories than the earlier maps, and distinguishes only cultivated land from other land-cover categories. This meant that the habitat selection analysis had to be reduced to an analysis of whether the birds selected natural land over transformed land or vice versa. Here it is important to clarify what is meant by "natural" land in this context.

There is an important distinction between transformed and modified land; transformed land is where the structure and composition of natural communities have been completely or almost completely changed, whereas on modified land only some aspects of the natural ecosystem have been altered (Macdonald 1989). For example, cultivated land and forestry plantations are transformed land, whereas natural veld where the indigenous large mammals have been replaced by livestock is modified land. The NLC maps identify only transformed areas, and do not distinguish between modified and natural land (this is a limitation of the methods used to classify land-cover types). Although not all land owned by farmers has been modified or transformed, the proportion of functionally fully natural land remaining in unprotected areas is undoubtedly miniscule.

The ways in which natural communities on modified land have changed have a significant effect on the flora and fauna that occur in these areas. Macdonald (1989) lists eight important ways in which vegetation communities alone have changed over large areas as a result of livestock grazing, and this does not include the changes to invertebrate and other faunal communities caused by livestock grazing and other management interventions such as insecticide application and predator removal. This implies that the percentage of the land that constitutes “natural habitat” for large terrestrial birds may in effect be a tiny proportion of that indicated in the NLC maps. However, it is also the case that much of the “natural veld” habitat type recorded by CAR participants would actually have been modified habitat, although this proportion would differ between different areas (e.g. “veld” in the Fynbos biome is unlikely to be used for grazing because of the preponderance of unpalatable plant species, whereas the majority of grazing land in the karoo biomes is in “veld”). This issue is therefore unlikely to represent a major problem with these analyses, but it should be borne in mind that “natural veld” in the context of this study is largely modified to some degree and unlikely to represent a truly natural habitat for large terrestrial birds.

The various types of land transformation represented within the CAR precincts are mentioned briefly in the previous section. Crops grown include wheat, maize, oats and other cereals, soya, sorghum, canola, pastures and livestock forage crops, sunflowers, fruit (including grapes), and many others to a lesser degree (Young et al. 2003). Sugar cane is an important crop along the east coast, in the humid subtropical zone (Allan et al. 1997a), but it does not feature in the areas I focus on in this thesis. Some of these crops tend to be more suitable as large terrestrial bird habitat than others, and the suitability of one crop may vary across the range of the species (Allan et al. 1997a, Young et al. 2003). For example, while Blue Cranes have colonised the Fynbos biome by taking advantage of the wheat fields and pastures there, the same types of farming appear to reduce habitat availability for them in their natural habitat in the Grassland biome. Many aspects of land management and farming affect large terrestrial birds, for example: the type of crop grown; the growing season of the crop in question; the rotation system used or combination of farming activities within each farm, which dictates the range of different types of habitat available to birds; whether the land is tilled or not; the use of pesticides; irrigation; drainage or damming of wetlands; livestock stocking density and the intensity of grazing; seasonality of veld burning, and of course whether direct persecution of birds is practised (Allan et al. 1997a, Young et al. 2003). It is likely that in a case such as the Blue Crane's differential preference for agricultural habitat in different areas, there is some crucial difference in management between the two areas that affects them (Young et al. 2003).

Other forms of land transformation tend to render land completely unsuitable for large terrestrial birds. The effects of mining and urbanisation upon species intolerant of human disturbance are obvious, and afforestation is inimical to any species that requires large tracts of open land. Whole sections of CAR routes that pass through afforested land have been removed from the routes, because no CAR species are ever seen in these areas (DJ Young, pers. comm.). Vineyards are similarly unsuitable for these birds, and they are very rarely if ever recorded in these habitats (CAR project, unpubl. data).

Climate change

Anthropogenic climate change has already been shown to be affecting many bird species in the northern hemisphere (Greenwood 2007). Such effects are yet to be observed in South Africa, but this may be partly because some of the strongest effects are seen on migrant species in more strongly seasonal (i.e. higher latitude) regions than South Africa. Migrants are perhaps more severely affected than many other birds because the timing of their migration becomes increasingly poorly synchronised with the timing of the seasons, because the cues they use to begin migrating are generally related to factors that will not change as the climate changes, e.g. day length (Chambers et al. 2005, Both et al. 2006).

Various attempts have been made to predict climate change in South Africa, and the vulnerability and responses to predicted climate change of bird species and other taxa (Erasmus et al. 2002, Simmons et al. 2004, Simmons and Barnard 2005, Huntley et al. 2006). The consensus prediction is that most current ecosystems and habitats may move southward and westward, and that the south-western-most ecosystems will "fall off the edge" of the continent (Simmons and Barnard 2005, Huntley et al. 2006). It has also been suggested that African birds will respond to changes in rainfall more than to changes in temperature (Simmons and Barnard 2005, Huntley et al. 2006), and because rainfall is predicted to become more erratic as climate change progresses, this could have serious consequences for birds. However, large birds are thought to have some advantage over small species, at least in the short term, because they are better buffered against food shortages, and nomadic species are likely to be at an advantage because they are pre-adapted to take advantage of unpredictable conditions and can more easily move to more favourable areas (Simmons et al. 2004). Thus many of the bustards and cranes may be more able to move with changing conditions than many species. On the other hand, they will probably be less able to adapt genetically to changing conditions than smaller species, since their reproductive output is lower and their generation times are longer, so in the long term they may be less able to cope with climate change (Simmons et al. 2004).

Aims of the thesis

Cranes are striking, charismatic birds which often gather in large flocks, and the three South African species have been well studied. Much is known about their biology, population status and the threats to their survival, and there are many ongoing crane conservation efforts in this country. Bustards, on the other hand, are on the whole shy and retiring, cryptically coloured, and seldom occur in large groups. Because of this they have drawn relatively little attention to themselves and are difficult to study, so comparatively little is known of their life histories and survival strategies; population estimates are at best educated guesses and at worst have not even been attempted.

The choice of species covered in this thesis was dictated by several factors. The project started life with the principal aim of using the valuable long-term CAR project data to increase our knowledge about the status of a relatively under-studied group of birds, the bustards. It was only later on that it was decided that the SABAP data should be used as well, because it would provide a different angle on the same problem. The species chosen, therefore, were those well enough covered by the CAR project data to make meaningful analysis possible. The Blue Crane was also included in the thesis because it was a threatened species that was particularly well covered by the CAR project and it was undergoing a dramatic shift of range and had an important story to tell. The bustards and cranes not covered in the detailed analyses were excluded because of a lack of sufficient CAR project data. The CAR project database, however, contains plentiful data on more common species, such as the Black-headed Heron and the Spur-winged Goose, and on other endangered species, such as the Southern Bald Ibis and the Secretarybird. It is beyond the scope of this thesis to analyse these data as well, but I hope that the methods developed here will in future be applied to the more common species as well, and that methods enabling the analysis of the sparser data will be developed.

The principal aim, therefore, of this thesis is to develop methods that enable us to make use of the high quality long-term data that are available to examine the status and conservation challenges of bustards and cranes covered by the CAR project. A secondary aim is to examine the variability inherent in CAR project data so as to provide some insight into the species that are most reliably surveyed by this project, and under what conditions the reliability of the survey increases or decreases.

Structure of the thesis

Each chapter of this thesis is written as an independent paper to facilitate the publication of results. Tables and figures are included at the end of each chapter, as are the references, which has resulted in some overlap in the methods and referencing sections of each chapter.

Chapter 2 introduces a method for assessing the reliability of CAR project data using additional consecutive day CAR counts. This method enables comparison between species and between subpopulations within species, and allows some inferences to be drawn about the factors that affect the reliability of roadcount data for large terrestrial birds.

Chapters 3–6 present detailed analyses of the CAR and SABAP data available for the Southern Black Korhaan (Chapter 3), the Blue Crane (Chapter 4), the Denham's Bustard (Chapter 5) and the Blue, Karoo and Northern Black Korhaans (Chapter 6).

Chapter 3 introduces the methods used in all four of these chapters, and the methods sections of Chapters 4–6 therefore refer largely to Chapter 3. The methods introduced are: population trend analysis using CAR project data; habitat selection analysis using CAR project data and the NLC maps; habitat use analysis using CAR project data; a graphical comparison of SABAP2 and SABAP1 reporting rates, termed a SABAP comparison map, and a national population index produced using CAR project data, SABAP reporting rates and relevant geographical data. An additional method introduced in Chapter 3 but not used in the remaining chapters is occupancy modelling using SABAP data.

Chapter 7 synthesises the results and presents one final analysis, a method allowing the core areas of diversity for a particular group of birds to be identified. In this case, the group of birds to which the method is applied is the bustards.

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Table 1: Summary of threats to South African bustard and korhaan species, with the species listed in order of priority for assessing. Species are grouped according to perceived threat levels, with the most threatened at the top of the table. Data summarised from a report compiled by Allan and Anderson (2010) following a survey of South Africa's bustard researchers.

Species	Threats
Denham's Bustard	Habitat destruction and degradation Powerline collisions Human disturbance (especially during breeding) Climate change
Ludwig's Bustard	Powerline collisions Human disturbance (especially during breeding) Climate change Poisoning (especially by poisons used for locust control)
White-bellied Korhaan	Habitat destruction and degradation
Kori Bustard	Habitat destruction and degradation Powerline collisions Human disturbance (especially during breeding)
Southern Black Korhaan	Habitat destruction and degradation Human disturbance (especially during breeding) Climate change
Blue Korhaan	Habitat destruction and degradation
Karoo Korhaan	Climate change Poisoning (especially by poisons used for locust control)
Northern Black Korhaan	Habitat destruction and degradation
Red-crested Korhaan	Habitat destruction and degradation
Black-bellied Bustard	Habitat destruction and degradation

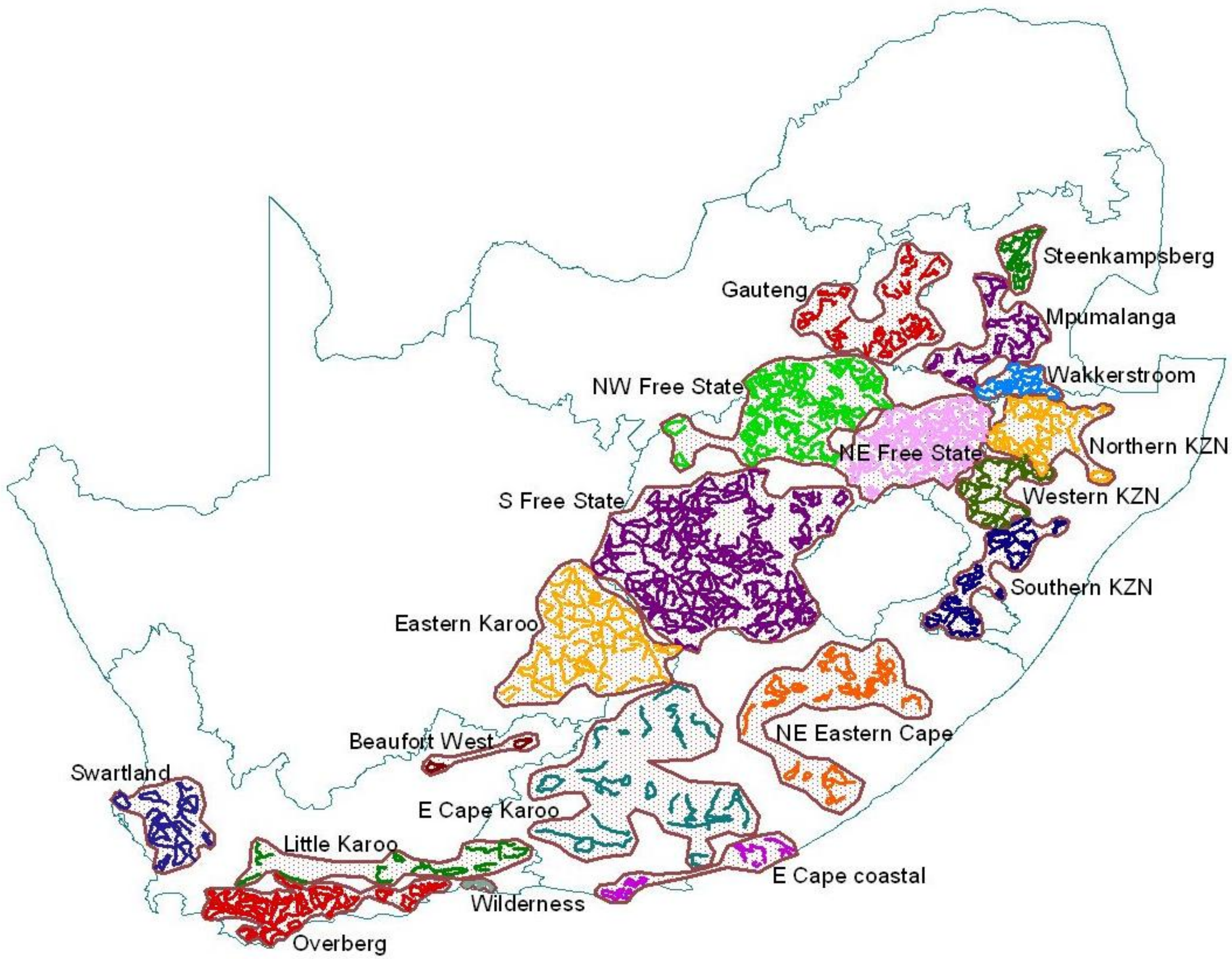

Figure 1: Coordinated Avifaunal Roadcounts (CAR) project survey routes (thick coloured lines) and precincts (areas outlined in brown) in South Africa. Initials stand for compass directions or, in the case of "KZN", KwaZulu-Natal. Precincts were defined on the basis of ecological characteristics by Young et al. (2003) (within precincts the natural vegetation type and climatic conditions are more similar than between precincts) and precinct names follow Young et al. (2003).

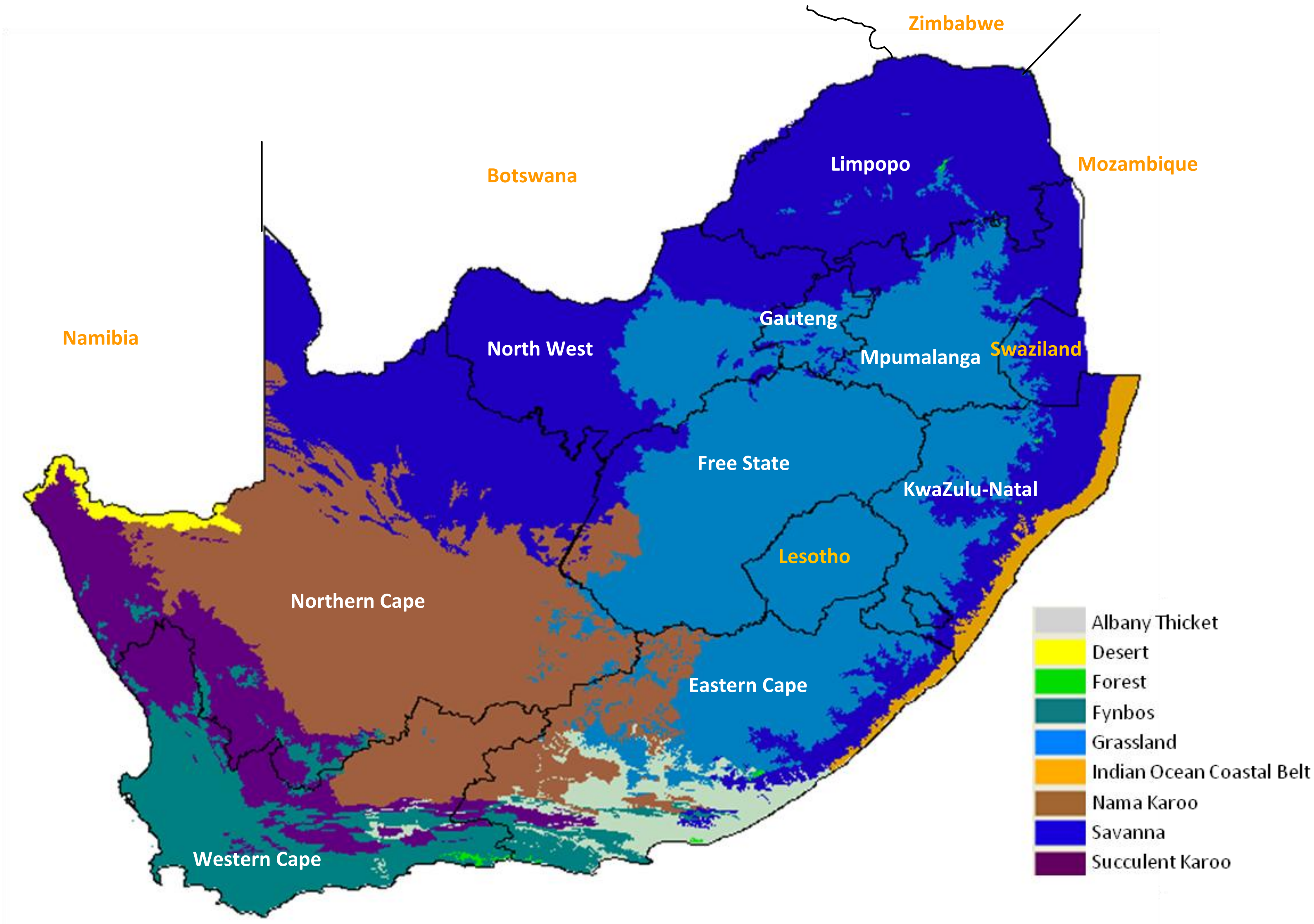

Figure 2: Biomes of South Africa, Lesotho and Swaziland (Mucina and Rutherford 2006). Province and country outlines are in black. Province names are shown in white, country names in yellow.

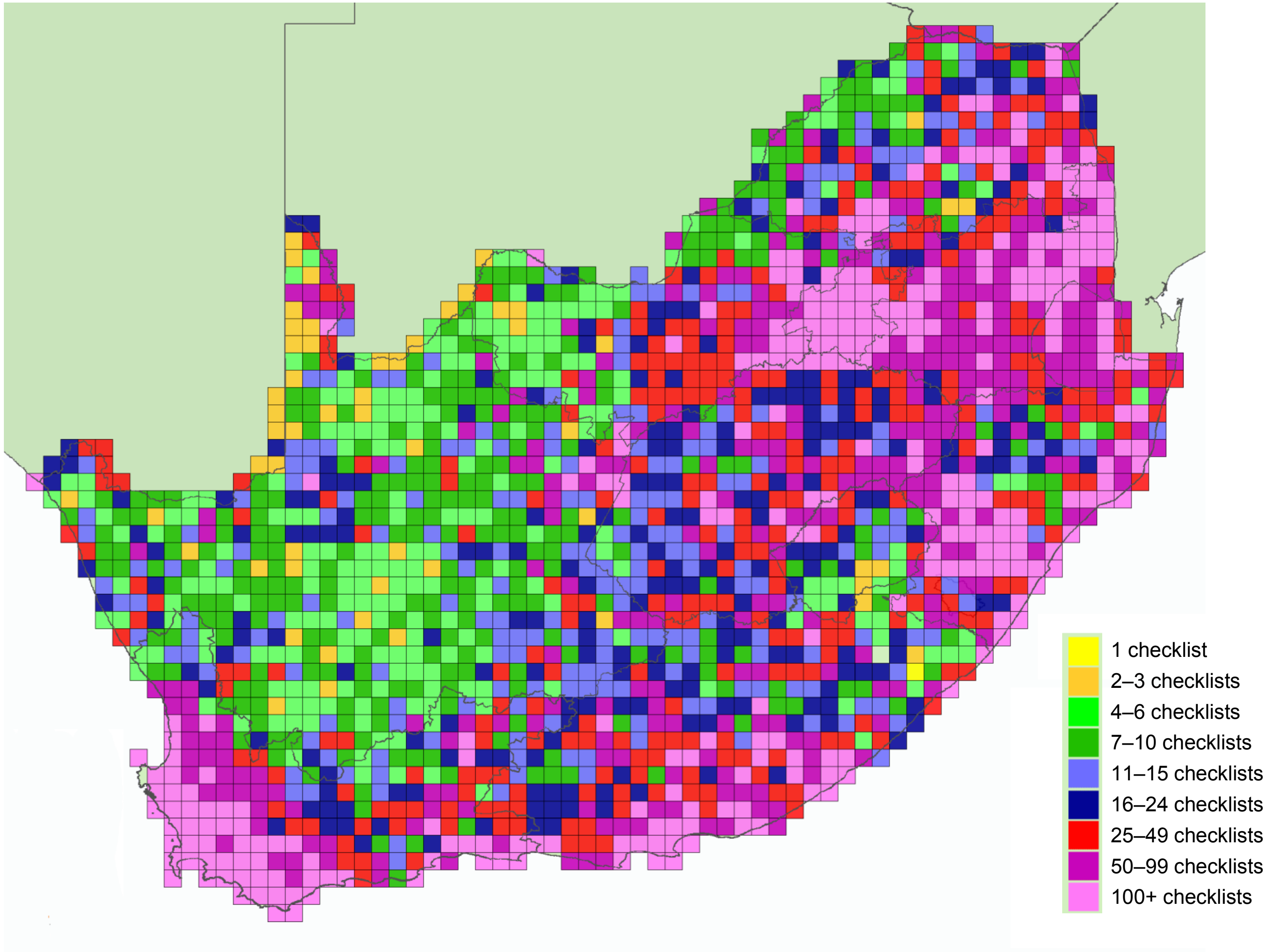

Figure 3a: The coverage attained in the first Southern African Bird Atlas Project (SABAP1; Harrison et al. 1997). Quarter-degree grid cells (QDGCs; 15' × 15') are colour-coded according to the number of atlas checklists submitted during SABAP1 (1987–1992).

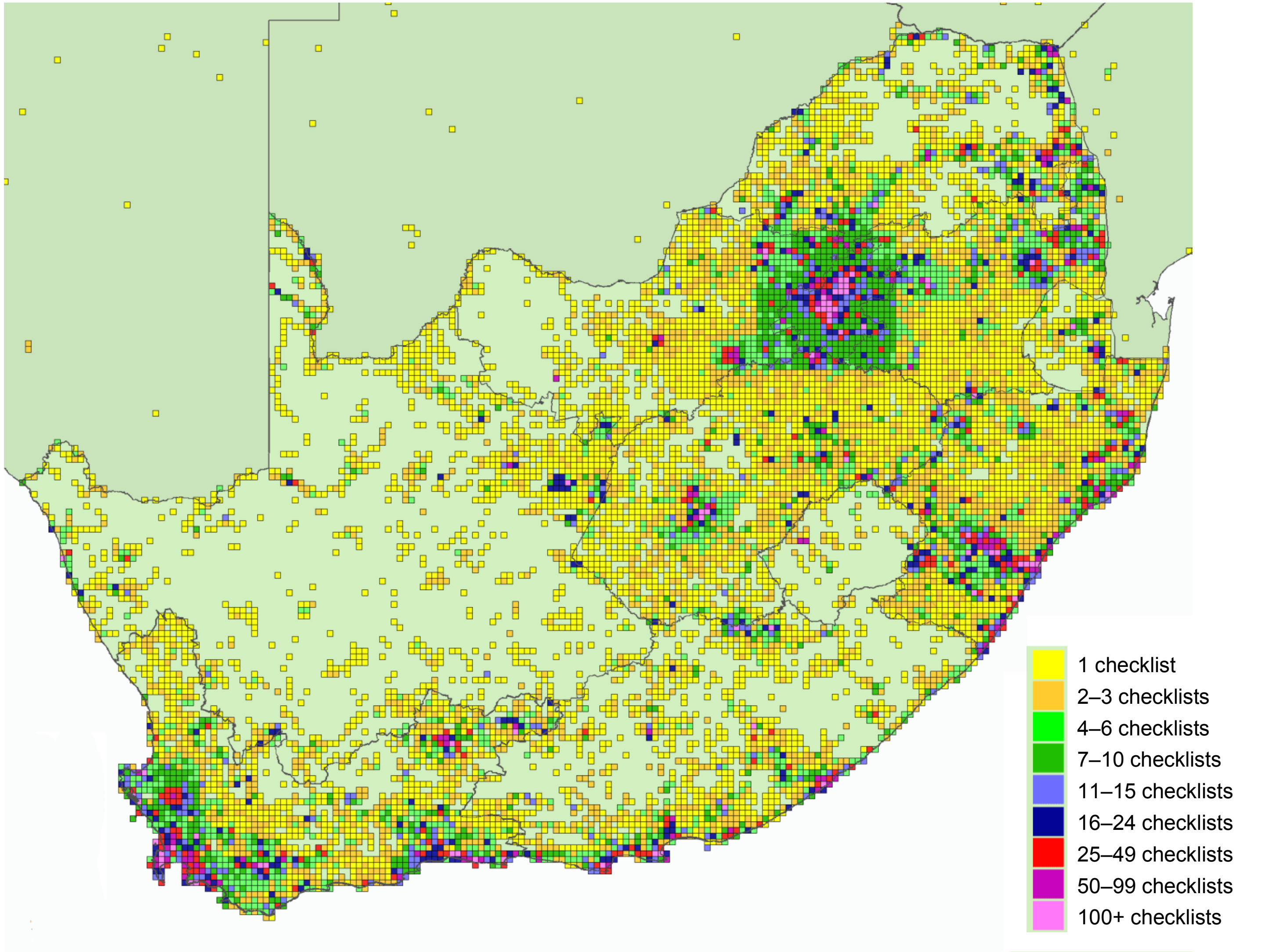

Figure 3b: The coverage of the second Southern African Bird Atlas Project (SABAP2) as at 10 February 2012. Grid cells shown are 5' × 5' ("pentads"). Pentads are colour-coded according to the number of atlas checklists submitted during SABAP2 (2007–).

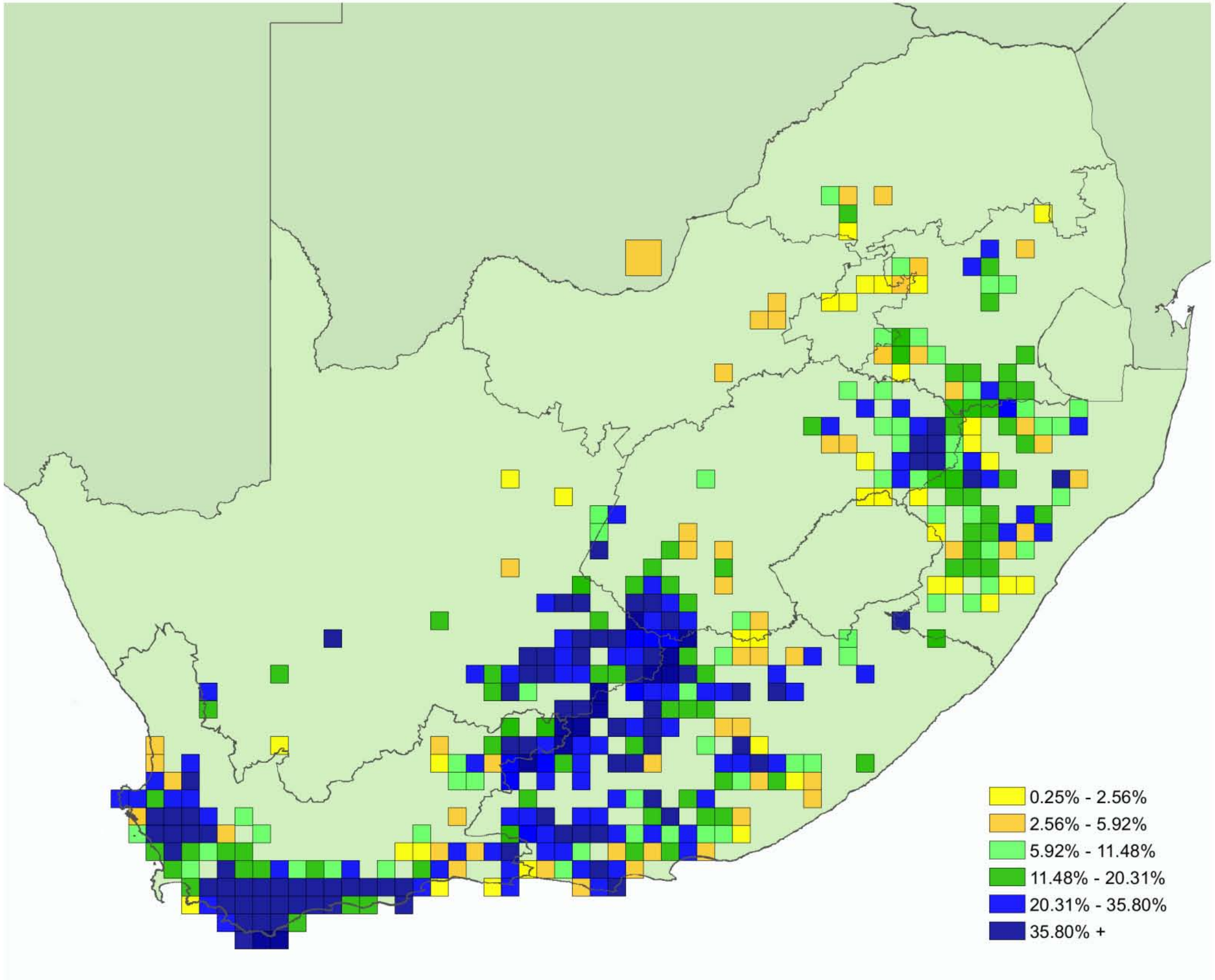

Figure 4: Derived reporting rates for the Blue Crane, calculated from SABAP1 and SABAP2 data (see text), extracted on 10 February 2012. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15').

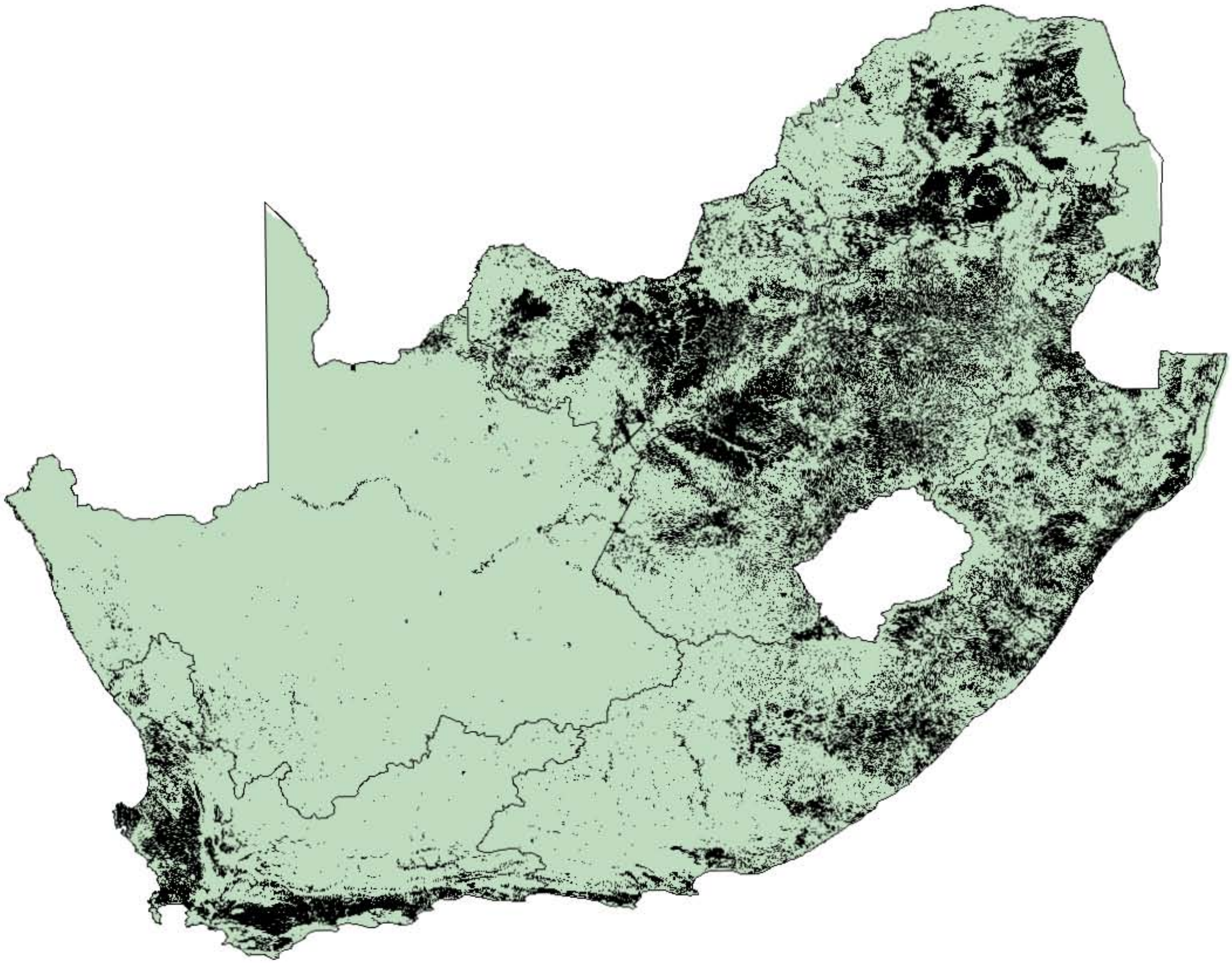

Figure 5a: The extent of transformed (black) and natural (green) land in South Africa in 2009. Produced from the NLC2009 map (SANBI 2009). The categories "natural" and "waterbodies" were combined to form the natural class; remaining categories formed the transformed class.

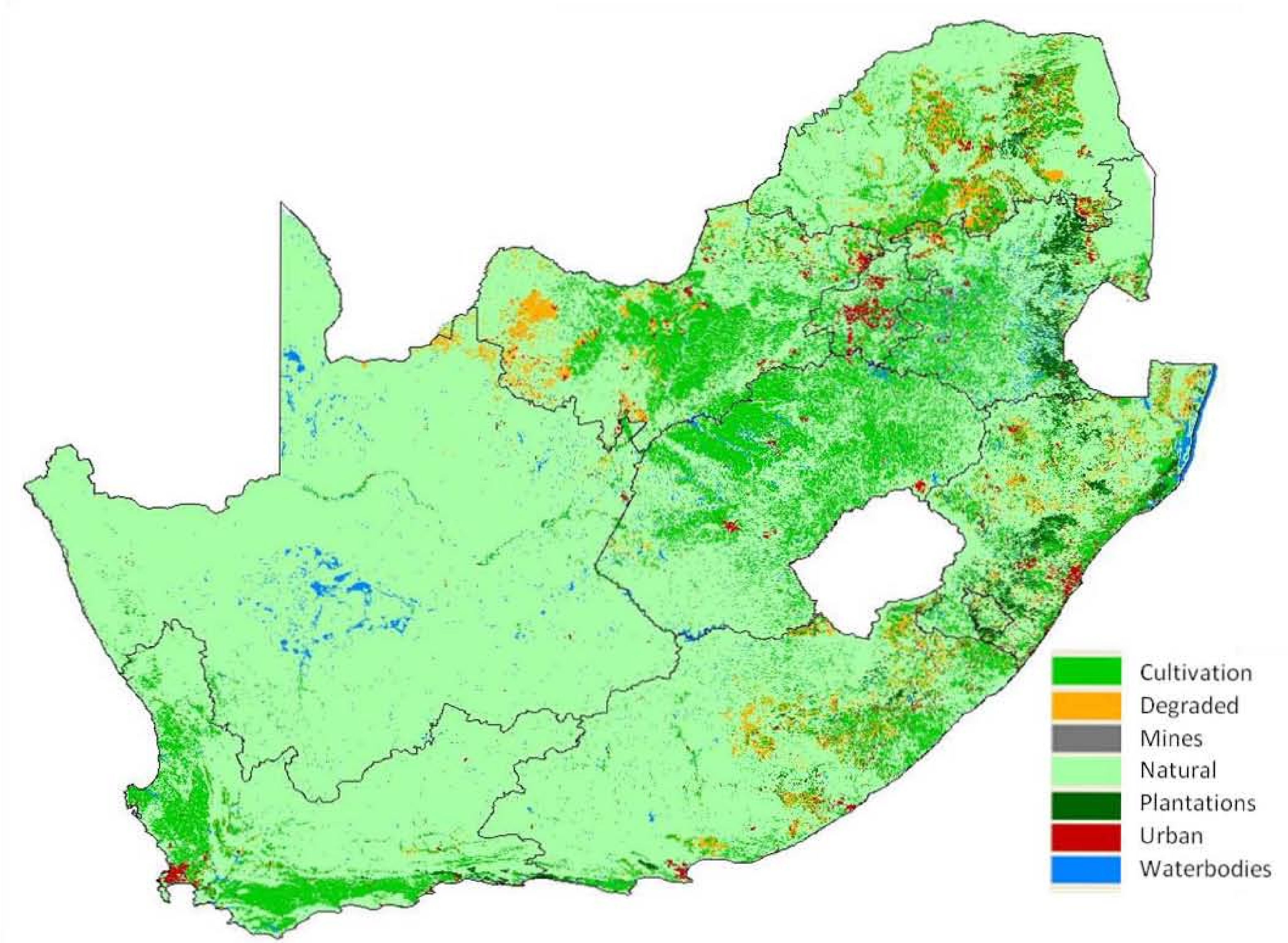

Figure 5b: National Land-Cover map of South Africa for 2009 (SANBI 2009).

Chapter 2

Investigation into the reliability of data from the Coordinated Avifaunal Roadcounts project

This initiative is particularly exciting because it takes the bird conservation struggle into the battlefield of privately-owned farmland, where many of the most vexing conservation problems arise

~ DG Allan, 1995

Bird studies have a valuable role to play, as one of several independent ways of monitoring some aspects of environmental change and, in a few cases, the best or only available monitor

~ RW Furness, JJD Greenwood & PJ Jarvis, 1993

Abstract

The Coordinated Avifaunal Roadcounts (CAR) project is a long-term public participation project which aims to monitor large terrestrial birds in agricultural landscapes in South Africa. It was established in 1993 in the Western Cape and expanded to cover much of the south-eastern half of the country by 2000. In 2010 over 300 routes were surveyed, covering c. 18 000 km of roads. Surveys were conducted annually in summer and winter and 35 bird species were counted according to a strict protocol. To assess the variability inherent in CAR data, additional, consecutive-day surveys of six CAR routes were conducted. The variability of the data was assessed by measuring the relative mean absolute difference between daily totals for route sections of a range of lengths, from 1 km up to the whole route. Species whose survey totals were most reliable were non-flocking, sedentary, and abundant, in descending order of importance. Exemplars were Northern Black Korhaan *Afrotis afraoides*, and Blue Crane *Anthropoides paradiseus* in summer and where it was abundant. Flocking species, such as Helmeted Guineafowl *Numida meleagris*, and relatively uncommon species that range over large areas, such as Secretarybirds *Sagittarius serpentarius*, were the least reliably surveyed.

Introduction

The Coordinated Avifaunal Roadcounts (CAR) project was established in 1993 by the then Avian Demography Unit of the Statistical Sciences Department at the University of Cape Town (Chapter 1, Young et al. 2003). The project began with the aim of monitoring populations of Blue Cranes *Anthropoides paradiseus* and Denham's Bustards *Neotis denhami* in the Overberg district of what was to become the Western Cape province of South Africa. Transect counts were conducted along fixed routes c. 60 km in length along roads in agricultural areas, annually in summer and winter, using a strict protocol. Members of local bird clubs and farmers from the area were encouraged to take part, and the project soon increased in size and coverage, expanding first to the Swartland district of the Western Cape (1994), then to a region in the south-east of the Northern Cape province centred around the town of De Aar (1995), and eastward and northward from then on, until in 2010 there were 19 active precincts, including 311 routes and covering c. 18 000 km of roads in agricultural areas of South Africa (Figure 1 in Chapter 1). The target species list had also increased to include 35 bird species and one small antelope. Most of the bird species surveyed were large terrestrial birds (birds which spend the majority of their time on the ground and are easily visible from a slowly moving vehicle, i.e. not smaller than birds such as Helmeted Guineafowl *Numida meleagris* or Southern Bald Ibis *Geronticus calvus*) but one low flying raptor, Black Harrier *Circus maurus*, was also included.

Transect bird counts have been carried out in many places throughout the world including South Africa, for many years (e.g. Hickey 1981, Summers et al. 1984, Spearpoint et al. 1988, Underhill et al. 1991, Young et al. 2003, Bart 2005), and the first roadside counts of birds were conducted in the USA in 1921 (Nice and Nice 1921). However, few studies assessing the precision (repeatability) of transect bird count data have been conducted. Two such examples are those by Summers et al. (1984) and Spearpoint et al. (1988). Both attempted to assess the precision of counts of wading birds carried out by walking along stretches of rocky shore. One of these studies involved a small number of repeated counts in Scotland in which either the count was carried out by two people simultaneously in the same direction, two people simultaneously in opposite directions, or on two days one or two days apart (Summers et al. 1984). The other involved monthly counts along a fixed stretch of rocky shore in South Africa, carried out by two people walking c. 10 m apart, one behind the other, with little or no communication between them (Spearpoint et al. 1988). Both studies found that precision varied between species; some species were relatively precisely counted, but the variation in totals of others was large. This was largely attributed to differing behaviours. Some species were cryptic and tended to stand still while foraging, making them less detectable, while others tended to form mixed flocks which swirled around observers when disturbed, and were therefore difficult to count accurately. Still others fed at a range of shore levels and were sometimes difficult to detect by an observer walking along the water's edge, or tended to fly inland to fields when disturbed, so that one observer might see them but the second would not. Some species were conspicuous, and the counts made by different observers were frequently identical.

Factors affecting the precision of roadcounts of large terrestrial birds undoubtedly differ somewhat from those affecting wader counts conducted on foot, but they presumably also affect the totals to some extent and to our knowledge have never been formally investigated. This study set out to assess the reliability of count totals recorded for a range of species surveyed by the CAR project. This was done by conducting repeated surveys of selected single routes on consecutive days and analysing the results using the relative mean absolute difference (relMAD), a measure of average deviation from the mean based on a measure developed by Spearpoint et al. (1988).

Methods

Extra CAR counts

Data collection

Additional surveys of selected single CAR routes were conducted, where possible around the time of one of the main surveys. The number of routes thus surveyed was limited by project funding and the number of volunteer CAR participants who were willing and able to participate. Extra counts of four routes (FS42, KU01, OV13 and SW07) were conducted by SDH (alone or, on KU01, with a different assistant each day), and of routes KU02 and OV07 by CAR project participants. Routes surveyed by SDH were selected on the basis of logistics and of count totals for species of interest. In order to assess the reliability of count data for the species focused on in this thesis, it made sense to select routes on which there was a good chance of seeing useful numbers of at least some of these species. Routes surveyed by CAR participants were chosen based on the fact that those were the routes they usually surveyed and were familiar with. Route selection was therefore not random but was performed in a manner that maximised the chances of obtaining useful data. All routes except FS42 were surveyed at the time of the main counts, such that the main counts could be used as one of the consecutive counts (the main counts were conducted by the regular counters for those routes, who in the case of KU02 and OV07 were the people who conducted the extra counts). OV07 was surveyed on three consecutive days in winter 2009, KU01 and KU02 on six and seven consecutive days in winter 2009 respectively, SW07 on five consecutive days in summer 2010, OV13 on five consecutive days in each of summer and winter 2010, and FS42 on four consecutive days in late spring 2009. The same protocol was followed for the extra counts as for the main surveys.

Analysis

The relative mean absolute difference (relMAD) from the mean was adapted for the present data from a measure developed by Spearpoint et al. (1988). It was calculated for each species-route combination, and for different section lengths of the routes. The routes were initially divided into 1 km sections and the relMAD was calculated as follows:

where x_{ij} is the section total for the ith day and the jth section, is the mean of the jth section over all days, the double sum is over both sections and days, N is the total number of observations (i.e. the product of the number of sections and number of days), and is the overall mean total for all sections and days. This figure was multiplied by 100 to give the percentage by which the relMAD value differed from the overall mean. This statistic measures the average extent to which the number of birds of a species counted along a particular 1 km section varied between days. Small values for the relMAD statistic indicate that the detailed distributions of birds, on a scale of 1 km, do not vary much between days.

The totals for the 1 km sections were then summed pair-wise, i.e. the 1 km sections were combined into 2 km sections, and the relMAD for the 2 km sections was calculated. This was repeated for as many section lengths as would divide evenly into the total route length, giving 12 section lengths for the 60 km routes (OV13, KU01 and KU02), seven for the 64 km route (FS42), eight for the 66 km route (OV07) and six for the 44 km route (SW07). Likewise, this measures variability between days over sections of the route of increasing lengths.

After inspection of these initial results, a bootstrap procedure was used to examine the potential spread of relMAD values. This was done where the total number of birds recorded over all the days was more than 20 or where the average number of birds seen per day was more than three (because of sampling error, results for birds seen at lower frequencies provided little or no useful information). The process described above was repeated for 1 000 bootstrapped samples of the 1 km sections (i.e. the sections were randomly sampled with replacement). The relMAD values for each section length were plotted in a scatter plot. This was also done for KU01 and KU02 joined together, since they were surveyed on overlapping days and cover very environmentally similar areas and could thus reasonably be treated as one route. This gave a total effective route length of 120 km, and 15 section lengths for which to calculate relMAD values.

Results

Species for which there were sufficient data to perform the bootstrap analysis were Black-headed Heron *Ardea melanocephala*, Blue Crane, Denham's Bustard, Grey Crowned Crane *Balearica regulorum*, Helmeted Guineafowl, Karoo Korhaan *Eupodotis vigorsii*, Ludwig's Bustard *Neotis ludwigii*, Northern Black Korhaan *Afrotis afraoides*, Southern Bald Ibis, Spur-winged Goose *Plectropterus gambensis*, Wattled Crane *Bugeranus carunculatus* and White Stork *Ciconia ciconia* (Table 1). Species which were excluded from this analysis due to insufficient numbers having been recorded were Black Harrier, Blue Korhaan *Eupodotis caerulescens*, Secretarybird *Sagittarius serpentarius* and Southern Black Korhaan *Afrotis afra*.

Trends in relative mean absolute differences from section lengths of 1 km up to the full route length were different for different species, and were affected by the regularity of sightings, total number of birds observed on the route and flocking behaviour (Table 1). Flocking behaviour was classified using data in Table 2 in conjunction with personal observations (SDH) and descriptions of each species in (Hockey et al. 2005). However, the general trend was for relMAD values to decrease with increasing section length following a broadly logarithmic curve (examples in Figure 1). The relMAD values for the original data were generally in the centre or lower half of the range of values for the bootstrapped samples, and the spread of values for the bootstrapped samples (as indicated by the standard deviation, Table 1, and displayed graphically in Figure 1) tended to increase with increasing section length.

Some examples of different types of behaviour of the relMAD values follow. Large numbers of Blue Cranes were recorded on route OV13 in both the summer and winter counts (893 and 1 477 birds respectively), but in summer almost three times as many birds were seen alone or in small groups (up to five birds) as in winter, whereas in winter 93% of birds were in groups of six or more (Table 2). RelMAD values for the original data were c. 20 percentage points smaller for the summer data than for winter, and 18–30 percentage points smaller for the bootstrapped samples (Table 1). Standard deviations for the bootstrapped summer data were also smaller than those for winter, by c. 10 percentage points. Thus the value and range of the relMAD values was smaller in summer counts than in winter (Figures 1a and 1b). RelMAD values for this species tended to decrease with increasing total number of birds seen, except on the OV13 winter count (Table 1, Figure 2).

Similar numbers of Spur-winged Geese were recorded on OV13 in summer and winter (169 and 174 birds respectively), but their flocking behaviour differed between seasons, which affected their relMAD values. In summer the average group size was 24.1 and 98% of the birds were in groups of six or more, whereas in winter the average group size was 3.6 and 50% of birds were alone or in smaller groups (Table 2). Mean RelMAD values remained around 100% for all section lengths for summer for the original data (Table 1). For the winter data they decreased from above 100% for 1 km sections to 57% for medium sections and 21% for the whole route. Figures 1c and 1d show that the behaviour of the relMAD values was similar to that for the Blue Crane for the winter data, but that for the summer data they remained approximately constant for all section lengths other than the whole route.

The Northern Black Korhaan had the lowest relMAD values of all the species in this study, and the spread of the relMAD values for the bootstrapped samples was consistently low (Table 1, Figure 1e, Figure 3). This species was never seen in groups and birds were relatively evenly spread out along the route (SDH pers. obs). In contrast Ludwig's Bustards were seen in groups sporadically spread out along the route (SDH pers. obs). The majority of their relMAD values were above 60% and the spread of the values for the bootstrapped samples was consistently large (Table 1, Figure 1f).

Helmeted Guineafowls on route KU02 were almost exclusively seen in large flocks (Table 2). Almost all of their relMAD values were above 130%, but the spread of values for the bootstrapped samples was relatively small (Table 1, Figure 1g). Black-headed Herons were seen singly or sometimes in small groups (Table 2), and similar numbers were seen on routes KU01 and KU02. The relMAD values for these two routes when combined into one 120 km route were similar to the lower of the two sets of values for the individual routes, although the spread was less (Table 1). The pattern of relMAD values for this species was similar to that for the Spur-winged Goose on OV13 in winter (Figure 1h).

Discussion

The lower a relMAD value is, the more reliably counted is the species in that season and on that route, because a low relMAD value implies that the number of birds recorded each day for that section length varied on average by a small percentage. Thus the Northern Black Korhaan was unquestionably the most reliably counted of the species analysed. Other species that were more reliably counted were Denham's Bustard

(OV07), Blue Crane (all routes), Spur-winged Goose (FS42, KU02 and OV13 in winter), Grey Crowned Crane (KU01) and Black-headed Heron (OV07, KU02). The least reliably counted species tended to be those that form large flocks, prime examples being Helmeted Guineafowl, and Spur-winged Goose in the Overberg in summer. Flocking behaviour alone, however, did not imply that a species was poorly counted; Blue Cranes in the Overberg in winter were still relatively reliably counted, even though the variability in totals was greater than in summer (this is also seen when long-term data from the Overberg precinct as a whole are analysed; Chapter 4). Blue Cranes, even when many of them were in large flocks, were still encountered in small groups relatively regularly along the route, and the large flocks tended to be in the same places each day (usually at feedlots; SDH, pers. obs). Helmeted Guineafowls and Southern Bald Ibises, on the other hand, were in a small number of groups and were variable from day to day; their group sizes varied and they were in different places each day and sometimes not visible on the route at all. White Storks and Spur-winged Geese in summer in the Overberg and Swartland were also in a small number of groups, were generally seen in the same or close sections of the route, but their group sizes were variable. Thus Helmeted Guineafowls and Southern Bald Ibises were not reliably counted, and Spur-winged Geese and White Storks in summer were sometimes somewhat more reliably counted than the former, but nevertheless much less reliably counted than the species which were more evenly spread out along the route.

Within a species, the more there were on a route the more reliably it tended to be counted, except if it flocks seasonally, as with the Blue Cranes and Spur-winged Geese on OV13. The species that were excluded from the analysis altogether were less common (e.g. Southern Black Korhaan, Black Harrier, Secretarybird, Blue Crane on the KU routes, Wattled Crane on KU01), at the edge of their range in the areas surveyed (Blue Korhaan) or in some cases effectively nomadic on the scale of a CAR route (e.g. Secretarybird). Species which are less common but sedentary or seasonally territorial may be relatively reliably counted over whole precincts, as appears to be the case for Southern Black Korhaans (Chapter 3) and Blue Cranes in Southern KwaZulu-Natal in summer (Chapter 4). However, species which are both less common and nomadic or range over large areas, such as Secretarybirds, are not effectively counted by a project such as this, because the chances of encountering them on any one survey are small. For example, out of the ten counts conducted for this study on route OV13, Secretarybirds were recorded twice: a pair on one day in winter and a single bird on one day in summer. The pair was probably a breeding pair whose territory overlapped to some extent with

OV13. However, with the chance of encountering them on a single count being only c. 20% it is unlikely that any reliable index of their population or estimate of population trends could ever be obtained from this project unless it were to expand considerably in scope and resolution. Southern Black Korhaans, on the other hand, were encountered on six of the ten surveys of OV13 (three days in each season), and all but one of them were in the same 1 km section of the route each time. Too few Denham's Bustards were recorded on OV13 in the summer to include them, but the species was reasonably reliably counted on the Overberg routes in winter. In Chapter 5 however it is apparent that overall the species is more reliably counted in summer in the Overberg, although it is seen in far lower numbers then than in the winter. Thus low numbers may have prevented species from being assessed in the present study, but this does not necessarily imply that they are not reliably counted by the CAR project as a whole, once entire precincts are considered.

Weather conditions are expected to affect count totals, and were recorded by CAR participants for every survey conducted. For OV13 in the winter the weather was similar (light breeze, overcast, cold, some mist and drizzle) on the first, second and fourth of the four days on which SDH conducted counts, and different (very windy, light cloud, cool) on the third day. Although the absence of mist and drizzle improved visibility, the wind made it difficult to hold binoculars or a telescope steady, hampering the observer's ability to identify birds at a distance. The number of Blue Cranes recorded was approximately half the previous day's total and 60% of the first day's, and only two Karoo Korhaans were recorded, compared with 19 and 18 on the days preceding and following this day respectively. However, only two Karoo Korhaans were also recorded on the first day, and the number of Blue Cranes recorded on the fourth day was almost the same as that on the windy day. Numbers of Denham's Bustards, Southern Black Korhaans and Spur-winged Geese recorded on the windy day were similar to those recorded on calm days. Thus while it is likely that weather conditions do affect count totals to some extent, the effect is not necessarily clear-cut or unidirectional, and to enable useful conclusions to be reached on this effect a much larger study would be necessary.

Due to the lack of sufficient volunteers and funds for paid assistants or reimbursements of fieldwork costs, extra counts of three routes (FS42, OV13, SW07) were conducted by SDH alone. Also, the CAR participants who regularly conducted the biannual surveys of KU01, OV13 and SW07 conducted the main counts that were considered as part of the series of consecutive day counts for these routes (since the extra counts of FS42 were conducted in November neither of the main counts for that year was included in that series). Also, the regular counters generally had at least one other person in the vehicle with them, sometimes as many as three, while SDH was alone except on KU01 (in which case she had a different assistant each day). It is also likely that SDH was a less experienced observer than the regular CAR participants in question, and certainly she was less familiar with the routes and which species to expect to see where. Thus it is to be expected that the totals would be higher for the main counts than for these extra counts; Summers et al. (1984) found that less experienced observers tended to record fewer birds than more experienced observers did. This did appear to be the case for some species, specifically Black-headed Herons on OV13 and KU01, Blue Cranes on OV13, Denham's Bustards on OV13 (winter only), Helmeted Guineafowls on KU01 and Spur-winged Geese on OV13 (winter only). For the rest, however, there was no apparent difference in the totals. Clearly this is not a conclusive statistical analysis and should not be used to draw any general inferences; it merely serves to demonstrate that in most cases including the main counts as part of the series analysed was not at all problematical. The differences in totals, where differences did exist, may also have been merely random (the difference in numbers of Helmeted Guineafowl, for example, are highly likely to have been random), but others, such as the Black-headed Heron and Denham's Bustard, were more likely due to differences in experience and the number of people looking for them.

The results presented here were similar to those reported by Spearpoint et al. (1988) and Summers et al. (1984): some species are more reliably or precisely counted than others, and aspects of their behaviour affect how reliably they are counted. Spearpoint et al. (1988) also examined within season and between year variability, and they found that the two types of variability were of the same order. This implies that it would be a mistake to infer population trends from even fairly large changes in count totals (they gave 30% as an example for some wader species) when conducting only one count each year, because they found that totals of the less reliably counted species could vary by at least that much within one season. They recommended repeated surveys conducted regularly as the reliable way to detect changes in abundance. Although the CAR project also relied on annual counts to detect trends in abundance (since summer and winter surveys were treated separately), many parts of an area were surveyed simultaneously by many observers. Assuming that some of the variation in daily totals obtained in the present study was caused by birds moving locally, much of this variation would have been accounted for in precincts where the area was well and closely covered by CAR routes. It would undoubtedly be preferable to conduct repeated surveys at regular intervals each season, were this is possible, but time and financial constraints preclude this possibility. However, where a species is identified from existing CAR project data as requiring more monitoring (e.g. Southern Black Korhaan, Chapter 3), it would be advisable to implement this recommendation and conduct as many repeated surveys as possible before changing management policies and conservation practices.

Conclusion

This small study shows that some CAR project target species are more reliably counted than others, and some are more reliably counted in some seasons than others and when present in greater numbers. In general, the conclusion is that the most reliably counted species are those present in larger numbers which distribute themselves fairly evenly along routes, and tend to form small groups or not to flock at all. Species which occur exclusively in large flocks which move over large areas (and therefore are encountered sporadically along routes) are the least reliably counted. Species which occur in low numbers may be reliably counted if they do not move great distances each day (e.g. Black-headed Heron, Southern Black Korhaan) but not if they do (e.g. Secretarybird). Although these general principles may apply broadly, the species-specific results presented here are applicable only to the precise areas studied; just as the conclusion for the Blue Crane was different for different regions, conclusions for other species may differ for areas not covered in this study.

To allow stronger conclusions to be drawn from existing and future CAR project data, this study should be extended and the process repeated on more routes over a greater area of the country. If more routes from each precinct were surveyed in this way, the count precision of each species in each precinct could be estimated with higher confidence (rather than restricting conclusions to just the specific routes on which consecutive day counts were conducted). It would also be desirable to develop a method for combining count totals for routes in one precinct, to allow the estimation of the count precision of rarer species.

For Chapters 3 to 6 of this thesis, these results imply that the results of the CAR population trend analysis for the focal species (Blue Crane, Blue Korhaan, Denham's Bustard, Karoo Korhaan, Northern Black Korhaan and Southern Black Korhaan) are most reliable where these species are most abundant, and when they exhibit least flocking behaviour. The caveat about flocking behaviour is only truly relevant to the

Blue Crane, however; none of the other species tend to form large groups, although some are often seen in small groups. The korhaans tend to be sedentary, but the Denham's Bustard is somewhat nomadic, especially out of the breeding season. The Blue Crane is territorial during breeding but more nomadic and often in large flocks when not breeding. This implies that analyses for these species' breeding seasons will be more reliable than those for their non-breeding seasons. Overall, however, these species fall into the category of species for which CAR count totals are, in general, most reliable.

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Table 1: Summary of analysis of consecutive day extra CAR count data. The relative mean absolute difference (relMAD) should be interpreted as the percentage by which the totals from the sections for all count days vary from the mean section total (see text). Route names indicate the precinct the routes were in: FS indicates Southern Free State, KU Southern KwaZulu-Natal, OV Overberg and SW Swartland. "Total" gives the total number of birds recorded over all consecutive day counts in a series. Medium sections were the sections of median or median+0.5 length; these lengths were 10 km (KU01, KU02, KU01+02, OV13), 11 km (OV07, SW07) or 8 km (FS42). The "Bootstrapped data" section gives the means and standard deviations (S) of the relMAD values calculated from the original data and 1 000 bootstrapped versions of the original data.

								Bootstrapped data relMAD					
					Original data relMAD			1 km sections		Medium sections		Whole route	
Species	Route	Season	Total	Flocking	1 km sections	Medium sections	Whole route	Mean	S	Mean	S	Mean	S
Black-headed Heron	KU01	winter	62	No	156.45	93.55	70.97	**157.08**	5.36	**112.56**	11.75	**82.87**	17.23
	KU02	winter	45	No	154.29	98.41	27.30	**154.65**	7.26	**98.12**	12.80	**49.17**	13.57
	KU01+02	winter	107	No	151.49	93.40	36.30	**151.61**	4.95	**100.61**	9.16	**46.24**	14.32
	OV07	winter	18	No	111.11	51.85	22.22	**112.08**	9.69	**61.99**	15.58	**31.69**	16.28
	OV13	summer	35	No	101.25	85.00	45.00	**108.58**	16.86	**88.92**	19.76	**56.82**	22.37
	SW07	summer	28	No	142.86	105.71	55.71	**145.33**	9.33	**104.89**	15.29	**74.18**	19.16
Blue Crane	FS42	spring	23	Small groups	108.70	86.96	36.96	**109.65**	12.66	**91.83**	19.34	**56.35**	26.97
	OV07	winter	975	Yes	64.55	24.75	20.92	**65.28**	13.69	**42.13**	11.88	**25.41**	11.55
	OV13	summer	893	Small groups	74.67	27.85	11.82	**75.56**	8.32	**36.56**	6.42	**18.20**	6.44
	OV13	winter	1 477	Yes	90.34	46.58	31.62	**93.20**	14.41	**66.06**	16.22	**41.75**	18.38
	SW07	summer	142	Small groups	112.39	49.58	19.44	**113.53**	10.08	**63.35**	13.92	**37.33**	16.08
Denham's Bustard	KU01	winter	26	Small groups	151.28	124.36	61.54	**153.68**	8.07	**123.37**	14.02	**73.40**	19.63
	KU02	winter	34	Small groups	134.45	98.32	79.83	**136.72**	11.21	**121.89**	15.49	**93.51**	15.40
	KU01+02	winter	60	Small groups	142.31	117.95	53.85	**144.41**	9.95	**119.24**	11.96	**65.83**	12.63
	OV07	winter	74	Small groups	81.98	27.93	11.71	**83.97**	17.97	**49.94**	15.14	**23.66**	13.69
	OV13	winter	82	Small groups	135.12	88.29	44.39	**135.30**	7.08	**91.88**	13.95	**59.56**	18.29
Grey Crowned Crane	KU01	winter	107	Small groups	141.43	64.17	34.58	**141.81**	7.71	**91.37**	13.64	**50.47**	15.56
	KU02	winter	29	Small groups	135.96	89.66	52.22	**137.90**	11.26	**110.63**	19.32	**69.57**	18.25
	KU01+02	winter	136	Small groups	137.34	68.17	18.55	**137.80**	7.13	**96.67**	11.86	**36.73**	12.10
Helmeted Guineafowl	KU01	winter	155	Yes	155.27	144.30	45.81	**156.62**	8.87	**140.37**	18.90	**92.23**	33.58
	KU02	winter	206	Yes	148.82	148.82	138.00	**154.55**	11.64	**152.46**	11.81	**145.90**	12.58
	KU01+02	winter	361	Yes	159.34	152.28	61.13	**160.04**	6.79	**148.57**	13.31	**91.83**	24.57
Karoo Korhaan	OV07	winter	13	No	112.82	71.79	41.03	**114.98**	17.16	**97.18**	26.85	**62.97**	31.20
	OV13	summer	33	No	146.67	96.97	40.00	**146.72**	5.96	**103.18**	14.87	**58.87**	13.91
	OV13	winter	49	No	125.96	102.98	77.45	**127.99**	12.37	**97.21**	12.84	**79.40**	13.57

Table 1 (continued).

Species	Route	Season	Total	Flocking	Original data relMAD			Bootstrapped data relMAD					
								1 km sections		Medium sections		Whole route	
					1 km sections	Medium sections	Whole route	Mean	S	Mean	S	Mean	S
Ludwig's Bustard	FS42	spring	55	Small groups	106.36	99.09	63.64	**120.47**	23.40	**112.13**	23.36	**85.87**	24.32
N Black Korhaan	FS42	spring	260	No	44.81	21.54	5.38	**45.07**	3.27	**20.82**	3.49	**8.64**	3.74
Southern Bald Ibis	KU01	winter	89	Yes	153.93	110.86	82.02	**154.04**	4.97	**130.12**	11.78	**97.25**	15.42
Spur-winged Goose	FS42	spring	55	Small groups	57.27	50.91	12.73	**66.44**	26.32	**54.45**	23.45	**26.74**	16.98
	KU01	winter	38	Small groups	150.88	85.09	56.14	**152.96**	7.82	**126.17**	16.33	**79.35**	18.88
	KU02	winter	1 204	Yes	116.92	69.41	28.90	**121.24**	17.52	**99.24**	20.51	**58.58**	25.94
	OV07	winter	94	Small groups	106.38	76.60	60.99	**107.15**	8.03	**73.26**	11.78	**61.47**	15.19
	OV13	summer	169	Yes	112.61	111.34	97.07	**118.71**	13.30	**116.82**	14.36	**109.07**	18.48
	OV13	winter	174	Small groups	111.45	56.65	20.58	**112.83**	7.25	**67.29**	11.15	**33.97**	13.70
Wattled Crane	KU02	winter	27	Small groups	147.09	122.75	76.19	**147.60**	6.21	**124.24**	15.49	**89.52**	18.84
White Stork	OV13	summer	348	Yes	102.14	68.87	47.22	**99.66**	18.07	**73.36**	21.00	**51.02**	22.80
	SW07	summer	53	Small groups	141.89	110.94	89.81	**142.33**	8.62	**115.05**	17.59	**96.23**	20.58

Table 2: Flocking analysis for species for which the bootstrapping analysis was conducted. Route names and Total column are as for Table 1. "Singles" indicates birds seen alone, "small grps" indicates groups of two to five individuals, "large grps" indicates groups of more than five individuals, and "no. of grps" includes birds seen alone. When several birds were recorded at one stop (indicated by the exact mileage recorded for the sighting) they were considered to be a group, although in fact they may have been in several smaller groups. Northern Black Korhaans were treated differently because they were only ever seen as singles (SDH pers. obs), even though several may have been recorded at one stop.

Species	Route	Season	Total	Mean group size	Number of singles	Number in small groups	Number in large groups	Number of groups	Number of small groups	Number of large groups	Flocking
Black-headed Heron	KU01	winter	62	2.1	21	19	22	30	6	3	No
	KU02	winter	45	1.6	17	28	0	28	11	0	No
	OV07	winter	18	1.0	18	0	0	18	0	0	No
	OV13	summer	35	1.8	15	10	10	20	4	1	No
	SW07	summer	28	1.6	12	16	0	17	5	0	No
Blue Crane	FS42	spring	23	1.8	5	18	0	13	8	0	Small grps
	OV07	winter	975	13.0	3	95	877	75	35	37	Yes
	OV13	summer	893	6.2	12	274	607	144	91	41	Small grps
	OV13	winter	1 477	18.2	4	104	1 369	81	39	38	Yes
	SW07	summer	142	4.2	3	73	66	34	25	6	Small grps
Denham's Bustard	KU01	winter	26	2.0	8	18	0	13	5	0	Small grps
	KU02	winter	34	2.4	5	29	0	14	9	0	Small grps
	OV07	winter	74	3.0	6	40	28	25	15	4	Small grps
	OV13	winter	82	2.6	13	48	21	31	16	2	Small grps
Grey Crowned Crane	KU01	winter	107	3.8	0	67	40	28	24	4	Small grps
	KU02	winter	29	1.9	1	28	0	15	14	0	Small grps
Helmeted Guineafowl	KU01	winter	155	22.1	1	0	154	7	0	6	Yes
	KU02	winter	206	51.5	0	5	201	4	1	3	Yes
Karoo Korhaan	OV07	winter	13	2.2	0	13	0	6	6	0	No
	OV13	summer	33	2.1	2	31	0	16	14	0	No
	OV13	winter	49	2.2	0	49	0	22	22	0	No
Ludwig's Bustard	FS42	spring	55	5.0	2	13	40	11	6	3	Small grps
N Black Korhaan	FS42	spring	260	1.0	260	0	0	260	0	0	No
Southern Bald Ibis	KU01	winter	89	4.9	4	25	60	18	9	5	Yes

Table 2 (continued).

Species	Route	Season	Total	Mean group size	Number of singles	Number in small groups	Number in large groups	Number of groups	Number of small groups	Number of large groups	Flocking
Spur-winged Goose	FS42	spring	55	2.8	7	33	15	20	11	2	Small grps
	KU01	winter	38	3.2	3	26	9	12	8	1	Small grps
	KU02	winter	1 204	40.1	2	12	1 190	30	4	24	Yes
	OV07	winter	94	2.9	10	52	32	32	18	4	Small grps
	OV13	summer	169	24.1	1	3	165	7	1	5	Yes
	OV13	winter	174	3.6	17	70	87	48	22	9	Small grps
Wattled Crane	KU02	winter	27	1.9	5	22	0	14	9	0	Small grps
White Stork	OV13	summer	348	5.9	14	89	245	59	28	17	Yes
	SW07	summer	53	3.3	10	9	34	16	4	2	Small grps

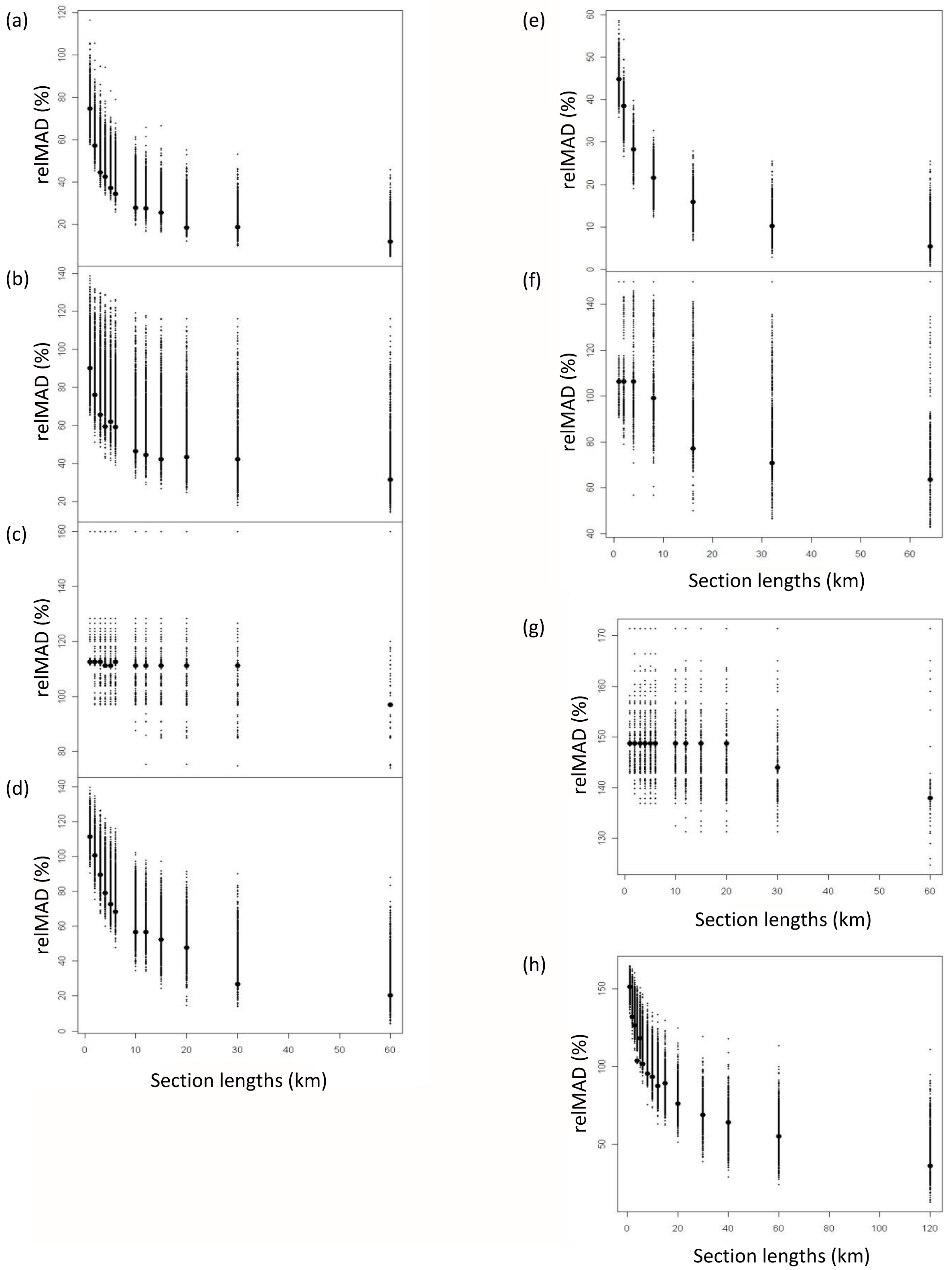

Figure 1: Examples of plots of relative mean absolute difference (relMAD) values for original data (large dots) and 1 000 bootstrapped samples of the original data (small dots) from consecutive day counts of CAR routes (a–d) OV13, (e–f) FS42, (g) KU02 and (h) KU01+02 (KU01 and KU02 treated as one route 120 km in length). Data shown are for Blue Cranes in (a) summer and (b) winter, Spur-winged Geese in (c) summer and (d) winter, (e) Northern Black Korhaans and (f) Ludwig's Bustards in spring, (g) Helmeted Guineafowls in winter and (h) Black-headed Herons in winter.

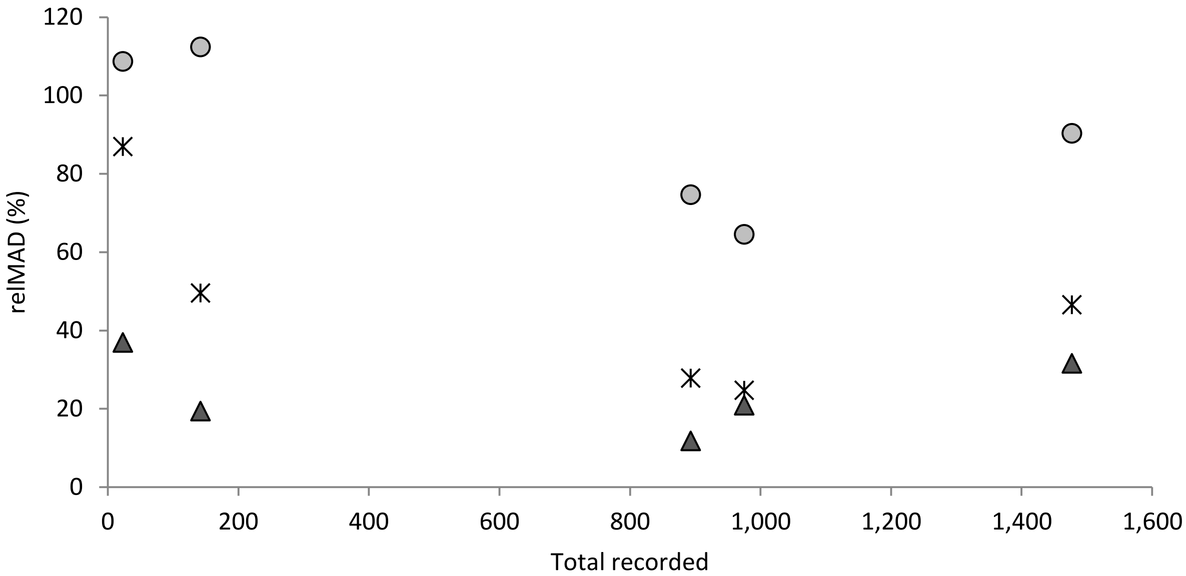

Figure 2: Relative mean absolute difference (relMAD) values for the original count data plotted against the total number of birds seen in each series of consecutive day CAR counts for Blue Cranes. Circles represent the values for 1 km sections, asterisks give the values for the medium sections (8 km, 10 km or 11 km sections, depending on the route; see Table 1), and triangles show the values for the route as a whole.

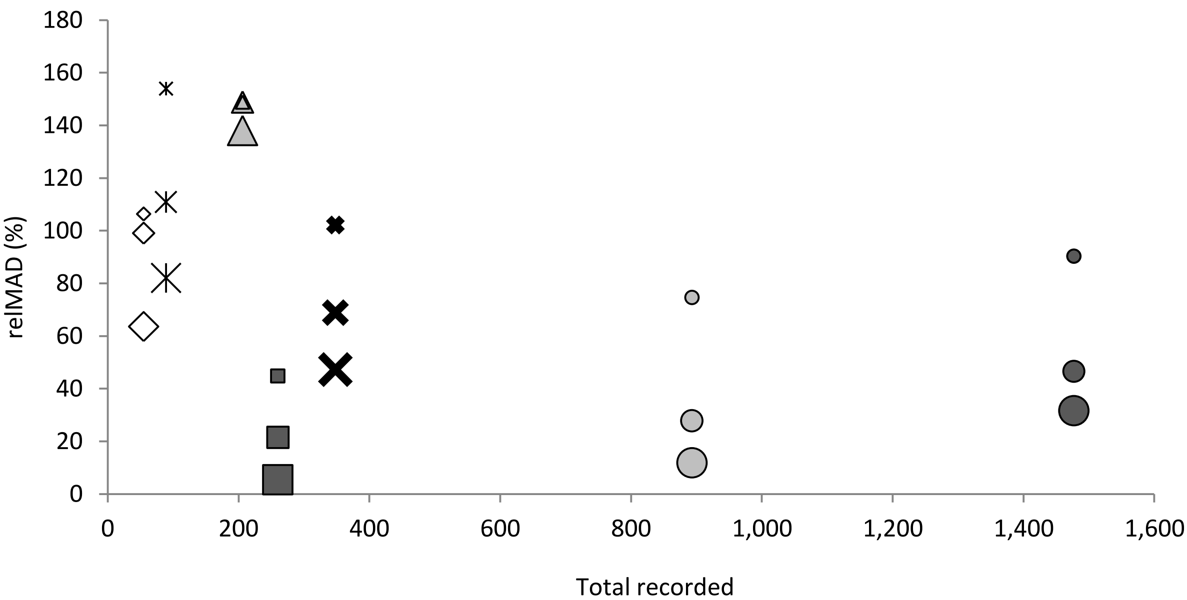

Figure 3: Relative mean absolute difference (relMAD) values plotted against the total number of birds seen for six species: Ludwig's Bustards on route FS42 (diamonds), Southern Bald Ibises on route KU01 (asterisks), Helmeted Guineafowls on route KU02 (triangles), Northern Black Korhaans on route FS42 (squares), White Storks on route OV13 (heavy crosses) and Blue Cranes on OV13 in summer (open circles) and in winter (filled circles). Small points represent the relMAD values for 1 km sections, medium points for the medium sections (see Table 1), and large points for the whole route (note that the relMAD values for the 1 km and medium sections for the Helmeted Guineafowl on KU02 are identical).

Chapter 3

Using long-term public participation surveys to document a species decline: the Southern Black Korhaan *Afrotis afra*

Bustards and human beings are largely
incompatible, and have little to do with each other

~ NJ Collar, 1996

Abstract

The conservation status of the Southern Black Korhaan *Afrotis afra* has not been assessed for taxonomic reasons; prior to 1994 it was considered conspecific with the widespread, abundant Northern Black Korhaan *A. afraoides*. Contrary to the latter species, the Southern Black Korhaan is restricted to a small range, much of which has undergone extensive anthropogenic transformation, and which is predicted to be strongly affected by climate change. Population trends produced from Coordinated Avifaunal Roadcounts (CAR) data suggested that this species declined in abundance in two out of three precincts between 1997 and 2010. A map comparing data from the first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992 and SABAP2, 2007–) indicated that the species declined in abundance in c. 80% of its range. Occupancy modelling using the same data confirmed this, showing that the korhaan declined in abundance and range in most of its range. CAR habitat use data showed that the species prefers to use natural habitats, but it does occur in transformed habitats in small numbers where natural habitat is much reduced. We recommend that this species is classified as Vulnerable because of past and probable future decreases in population and its vulnerability to ongoing land transformation, climate change and possible increased predation.

Introduction

The Southern Black Korhaan *Afrotis afra* has never been considered for listing on the IUCN Red List (BirdLife International 2012) for taxonomic reasons. The Southern Black Korhaan, originally classified as a distinct species in the 19th century, came to be regarded as conspecific with the Northern Black Korhaan *A. afraoides* in c. 1950 (Crowe et al. 1994). In 1994 the two species were again split on the basis of a detailed study of their behaviour, morphology, ecology, distribution and genetics (Crowe et al. 1994, Allan 2005b). The species recognised for the latter half of the 20th century, Black Korhaan *Eupodotis afra*, of which the vast majority is now regarded as *A. afraoides*, had a large range and population, and was not considered under threat. At the time of the workshops which preceded the publication of Barnes (2000), the conservation status of the Southern Black Korhaan was considered separately to that of the Northern Black Korhaan. On the basis of the data available then, however, it was decided to allocate the Least Concern status to the Southern Black Korhaan (K Barnes, pers. comm.). The range of the Southern Black Korhaan is substantially smaller than that of the Northern Black Korhaan, however, and its preferred habitat has been altered to a greater extent (Allan 2005a, 2005b).

The Northern Black Korhaan occurs primarily in the extensive grass-dominated summer-rainfall biomes in the interior of southern Africa (the Grassland, Savanna and eastern Nama Karoo biomes). The Southern Black Korhaan, however, is restricted to the non-grassy, winter- or mixed winter-summer rainfall Fynbos and Succulent Karoo biomes and the extreme south of the Nama Karoo biome, in a narrow strip along the southern and western coastlines of South Africa (Figure 1a; Crowe et al. 1994). Birds of this south-western corner of southern Africa are considered potentially the most threatened by climate change in southern Africa (Huntley et al. 2006). Impacts of climate change on birds and other taxa are already evident elsewhere in the world (e.g. Parmesan and Yohe 2003, Visser et al. 2004, Visser and Both 2005, National Audubon Society 2009); effects of other environmental changes already acting on the Southern Black Korhaan may therefore be aggravated by climate change.

The limited literature on the Southern Black Korhaan suggests that it was more common in the first half of the 19th century, and even up until the 1980s, than in the first decade of the 21st century (Stark and Sclater 1906, De Klerk 1941, Uys 1963, Skead 1967, Uys and Macleod 1967, Clancey 1973, Uys 1988, Hockey et al. 1989). For example, they were described as "very common" and "certainly the most abundant of all the game birds throughout the Cape Colony" by Stark and Sclater (1906), as one of the dominant species of coastal Fynbos by Uys and Macleod (1967), as locally common to common by Clancey (1973) and as a "common resident" by Hockey et al. (1989). The species' distribution in 2012 appears to be fragmented, and atlas reporting rates are smallest in the centre of its range (Figure 1b). In light of this and strong anecdotal evidence that the species is becoming less common (e.g. P Albertyn, F Hellman and DJ Young, pers. comms), as well as the inevitable additional challenges of climate change, its conservation status requires re-evaluation (Uys 1988, Allan 1997, Allan and Anderson 2010).

Two important public participation projects in South Africa can help detect changes in this species' status: the Coordinated Avifaunal Roadcounts (CAR) project (Chapter 1, Young et al. 2003) and the first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) (Chapter 1, Harrison et al. 1997, Harrison et al. 2008). This paper uses the available data to assess the status of the Southern Black Korhaan and to improve our understanding of its needs and the threats to its survival. CAR project data are analysed to produce population trends and to examine habitat use and selection. SABAP1 data are then compared with SABAP2 data graphically and by means of occupancy modelling to detect changes in distribution and relative abundance over time. Finally, population trends from the CAR project are combined to produce a national population index for the species. None of these methods has been used in this context before, and this paper is thus a novel approach to the analysis of two types of long-term survey data for the purpose of assessing the conservation status of a species.

Methods

CAR project

Data collection

The CAR project was initiated in 1993 in the Overberg region of the Western Cape, and expanded to cover much of the south-eastern half of South Africa over the following eight years (Chapter 1, Young et al. 2003). Southern Black Korhaans were included in the list of species surveyed in 1997 in the Western Cape and in 1998 in the Eastern Cape. The routes, which were primarily through agricultural areas, were surveyed twice a year, once in summer and once in winter. Korhaans encountered along the route were counted according to a strict protocol, and other relevant variables were collected (Chapter 1). Although the distance visible from the road is greater in many places, it is likely that 1 000 m is the maximum distance at which Southern Black Korhaans are visible when using binoculars, since they are fairly small birds (Allan 2005b). We thus interpret the counts as an index of the number of Southern Black Korhaans within a transect 2 000 m wide, symmetrically placed on either side of the route. However, CAR observers did not record the distance from the road of each sighting, precluding the application of “distance sampling” (Buckland et al. 1993) to the data; it was therefore not possible to transform the counts into densities. Thus one of the constraints imposed by the data collection protocol is that the results need to be expressed in linear units; the convenient metric is birds per 100 km.

Population trends

The CAR routes were classified into “precincts” — ecologically distinct areas with similar vegetation and climate characteristics — based on the precincts used in the Mazda CAR report (Young et al. 2003) and by examining vegetation maps (Mucina and Rutherford 2006) of areas surrounding any new routes. Data for each precinct were analysed separately for summer and for winter. Only precincts and seasons with sufficient data for a meaningful analysis were used; the estimated total number of birds for the entire precinct and period both counted and imputed (see definition in the following paragraph for precise meaning given in this analysis) was greater than 100, or if less than 100, the percentage of the total counted and imputed was less than 10%.

The Underhill index (Underhill and Prŷs-Jones 1994) was applied to the CAR count data to impute values for missing surveys. This method addresses the problem of missing data, which is inevitably encountered when dealing with survey data, especially involving volunteer participation (Underhill and Prŷs-Jones 1994). The method assumes a multiplicative model, in which abundance trends on each CAR route follow the pattern of the precinct as a whole, and estimates of missing observations were based on this model. Provided that the number of missing surveys for routes is small, it provides a good estimate of the total population which would have been observed in each precinct had all its routes been surveyed (Underhill and Prŷs-Jones 1994). Limits therefore need to be set by the user on the extent of missing values to be imputed, based on experimentation (Underhill and Prŷs-Jones 1994). After a series of trials, we decided that, in order to be included in the calculations, a route had to have been surveyed a minimum of six times in the season being considered. The upper limit to the proportion of the overall total of birds that was imputed by the index was set at 25%; if the percentage imputed was greater, data (either routes or years at the start or end of the time period) were excluded based on an examination of the output. The years 1997 and 1998 were excluded from the winter and summer analyses respectively for the Swartland precinct. This was done because there was a delay between inclusion of the species in the project and all observers in this precinct becoming aware of this change (DJ Young, pers. comm.), and totals for those years were therefore unreliable. Count totals for each precinct were summed and converted to an annual statistic: birds per 100 km of road surveyed. The distance of road within the precinct used for this calculation was calculated separately for every analysis, based on the routes which had been included in that specific analysis. This distance was therefore not always the same for a precinct in different seasons, or for the same precinct when analysed for different species (Chapters 4–6).

In order to provide a visual guide to the results, a smoothed curve was fitted through the annual density values for each pentad using a method developed by Underhill et al. (2006). This method calculates the rate of population increase or decrease for each year by fitting weighted linear regressions to each year, assigning the highest weight to the target year, slightly smaller weights to the two years on either side of the target, and weights to the other years diminishing with distance from the target year, using an exponential decay function with a user-chosen smoothing parameter, chosen on the basis of experimentation to provide a visual summary of the pattern of population change (Underhill et al. 2006). It therefore elucidates the general trend in the data, without forcing the trend to conform to any particular mathematical relationship. The smaller of either one or 5% of the median of the annual density values was added to all values before taking logarithms. A value of three was chosen as the value for the smoothing parameter (rather than two as in the reference cited). The effect of increasing this value is to spread the weights out slightly on each side of the target year, so that the influence of data values that are farther away from the target year increases. This change was necessary because the numbers of large terrestrial birds observed on the CAR counts were inherently more variable than the numbers of African Penguins *Spheniscus demersus* used in Underhill et al. (2006), and therefore it was necessary to spread the weights out slightly wider to better elucidate the trends.

A guide to the annual rate of population change was estimated from these weighted linear regressions as *e* to the power of the slope of the smoothed curve at each year point, and expressed as the percentage rate of change. This was calculated for each year, and was used to suggest points of inflection in the trajectories of population growth or decline. The point of inflection of a curve is where the rate of increase or decrease changes from negative to positive or vice versa, in other words where the second derivative is zero. This has been used in a wide range of applications to identify the point in time at which a trend begins to change; the points of inflection might well be the dates at which the drivers of population increases or decreases started operating (eg. Leach 1981, Fuller et al. 1995, Lyver et al. 1999, Comber and Gavin 2004, Underhill et al. 2006).

The proportion of variance unaccounted for by the trend line (termed “R^2”) was calculated as the ratio of the variance of the totals with respect to the trend line to the variance of the data series as a whole. Standard deviation (SD), coefficient of variation (CV) and means of totals and annual increments were also calculated.

Habitat use

The habitat use data collected by CAR project participants were extracted and summarised. All available data were used, including the few observations made before the species was officially included in the project, because this did not violate any assumptions as it would have done for the trend analysis. Additional precincts were included which did not have sufficient data for the population trend analysis, but did for the habitat selection analysis. Precincts were included if the number of routes on which birds were observed in at least one of the seasons was five or more, irrespective of the number of birds observed.

CAR project participants collected data at the locations at which Southern Black Korhaans were present and not in the landscape as a whole. The National Land-Cover maps for 2000 and 2009 provided consistent data covering the entire study area for the time period in question (NLC2000 and NLC2009 respectively) (CSIR and ARC 2005, SANBI 2009).

Habitat selection in relation to habitat availability was analysed by comparing the proportions of natural and transformed land available to the proportions of birds seen in each type of land in each precinct. The proportions of natural and transformed land available were calculated from both the NLC2000 and NLC2009 maps. All classes of land other than natural vegetation classes and waterbodies were combined to form a single "transformed" land class, and the remaining categories were combined to form a "natural" class (man-made and natural waterbodies, including wetlands, are not distinguished in the maps).

Based on the interpretation of the distance visible from the road above, ArcView 3.1 (Environmental Systems Research Institute Inc. 1998), was used to form a buffer zone of width 2 000 m around each CAR route (i.e. 1 000 m on each side of the road). This was overlaid with the transformed/natural layer produced from the land-cover maps in order to calculate the percentages of transformed and natural land available within the area visible from the road. The percentages of transformed and natural land were calculated for each precinct for each NLC map, and this was compared to the percentages of birds seen in each habitat type in each precinct using the Jacobs index (Jacobs 1974). Jacobs index values range between +1, indicating total positive selection, and –1, indicating total negative selection. The "sign test" was used to evaluate whether the number of routes in a precinct for which the index value was positive differed significantly from the number for which it was negative (Conover 1971).

Habitat use data from the CAR project were also summarised graphically to gain some insight into the types of transformed land used by the species in different parts of its range. Habitat categories that were poorly represented were combined into broader categories (e.g. ploughed land, mowed land and other types of farmland in which birds were rarely seen were combined to form the category "Agric Land") to aid interpretation.

SABAP

Data collection

The first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) represent distinct iterations of southern Africa's largest-scale bird monitoring project (Harrison et al. 2008). The protocol used for SABAP1 (1987–1992) was described in Chapter 1 and by Harrison and Underhill (1997), and for SABAP2 (2007–) in Chapter 1 and on the project's website (http://sabap2.adu.org.za/). For the purpose of this analysis, the sampling unit from the atlas projects was a dated checklist of species for the unit of grid cell, with a 15 minute grid for SABAP1 generating quarter degree grid cells (QDGCs) and a five minute grid for SABAP2, generating "pentads," so that there are nine pentads per QDGC (Chapter 1).

Occupancy modelling

Although the atlas projects were designed primarily with the aim of detecting and monitoring the ranges of bird species, and thus involved collecting only presence/absence data and not counts of individuals, a relatively recent innovation in population modelling, known as occupancy modelling, has made it possible to glean information about population trends from presence/absence data (MacKenzie et al. 2006). This type of modelling estimates not only site occupancy, but also detection probabilities for the species of interest. The primary purpose of estimating detection probabilities is to allow more accurate estimation of occupancy. However, we propose here that if temporal and/or spatial trends in detection probability become apparent, and assuming other factors affecting detection, such as habitat structure or behaviour, have remained constant, this allows inferences about trends in the abundance of the species. In other words, a change in detection probability is related to a change in abundance.

The atlas databases were queried for data from the range of the Southern Black Korhaan, which was defined in ArcView 3.1 by digitising a polygon around the QDGCs from SABAP1 in which the species was recorded, leaving a margin as wide as possible around this area. A wide margin was desirable, to capture any range expansion that might have occurred in SABAP2, and also to include as representative as possible a sample of each biome represented in the area. The margin could not be made very wide however, because during SABAP1 the Northern and Southern Black Korhaans were recorded as one species, so all QDGCs in which the Northern Black Korhaan were inferred to have occurred, based on Crow et al.'s (1994) analysis of the two species ranges, were removed. Fortunately the two species have limited range overlap, in two small areas of the Eastern Cape and the Western Cape, so they could be separated with confidence. The entire area of overlap was removed, to eliminate the possibility of including QDGCs in which the Northern Black Korhaan was recorded (Figure 2). The data were exported on 31 January 2011 as a complete set of atlas checklists, summarised to QDGC, date and the presence or absence of Southern Black Korhaans. For the occupancy modelling the QDGCs were treated as sites, so checklists from SABAP2 pentads were assigned to the QDGC in which the pentad was located. The checklists were sorted in date order, and all QDGCs which did not appear in both the SABAP1 and SABAP2 datasets were removed.

For the occupancy modelling, the SABAP1 data were treated as season one, and SABAP2 as season two. Two sets of covariates were used in the analysis. The first was biome, based on Mucina and Rutherford (2006). ArcView 3.1 (Environmental Systems Research Institute Inc. 1998) was used to calculate the percentage of each biome per QDGC, and these percentages were used as covariates (one for each biome). Biomes which occurred in small areas within the species' range, and in which the species did not occur, were excluded (Allan 2005b). Otherwise the model was dominated by these areas because they were different from the rest of the range in terms of Southern Black Korhaan abundance. Biomes excluded initially were Coastal Belt, Forest and Desert (representing 0.33%, 1.24% and 2.69% respectively of the area used for the model, i.e. the range of the Southern Black Korhaan plus a margin). After initial runs of the model, Grassland and Savanna, representing 13.69% and 8.30% of the area respectively, were also removed, because Southern Black Korhaans also tend not to utilise these habitats; consequently they were not useful in the model and removing them allowed a more nuanced interpretation of the differences between the biomes in which the species does occur.

As second covariate we used the percentage of each QDGC that was anthropogenically altered. These data were derived in the same way as described above for the habitat selection analysis, but were taken only from the NLC2000 map, since it was impossible to incorporate two different time-steps of a covariate into the models as they were constructed in the software we used. We decided to use this map rather than the NLC1994 or NLC2009 versions, because the year 2000 was closest to the midpoint of the time span under consideration. The map obtained was overlaid with the QDGC grid so that the percentage of each QDGC classified as altered could be calculated, and this percentage was used as the additional covariate.

The occupancy models were run in programme PRESENCE 3.1 (Hines 2010). The four biomes included in the model (Nama Karoo, Succulent Karoo, Albany Thicket and Fynbos) and season (SABAP1 or SABAP2) were used in different combinations in the models. PRESENCE offered several different parameterisation options for multi-season models, the default being to estimate occupancy probabilities for season one, detection probabilities in both seasons, and the probabilities of local extinction and site colonisation between seasons. The probability of occupancy in season two was therefore derived from the estimated parameters. This default option was used to identify the optimal model, because this is the parameterisation recommended by MacKenzie et al. (2006) as numerically stable.

We tested whether the parameter estimates for SABAP1 were significantly different from those for SABAP2 using likelihood ratio tests (LRT). However, the default parameterisation did not allow occupancy to be held constant across the seasons, so it was necessary to use an alternative parameterisation which estimated seasonal occupancy and site colonisation probabilities, along with seasonal detection probability (leaving the probability of local extinction to be derived from these estimates). The significance of differences between seasonal detection probability estimates was assessed using the original parameterisation. Alternative parameterisations of the same model, using the same data, are comparable in this instance (MacKenzie et al. 2006). Nested models were compared using LRT, holding one parameter constant for each comparison.

The statistical programming language R was used both to prepare the data for PRESENCE and to apply the necessary conversions (inverse logit) and calculations to the results in order to convert them back into actual probability estimates.

SABAP comparison map

We used a visual method, termed a SABAP comparison map, to examine the changes in reporting rates for the species from the first atlas project to the second, using all data submitted up until 10 February 2012. Reporting rate was defined as the proportion of atlas lists submitted for a QDGC which reported the Southern Black Korhaan. Because reporting rate is related to abundance, albeit in a non-linear (usually logarithmic) manner (see below, and e.g. Underhill and Hockey 1988, Underhill et al. 1992, Allan 1994, Robertson et al. 1995, Allan et al. 1997, Griffioen 2001, Harrison et al. 2008), it is possible to infer changes in abundance from changes in reporting rates. However, because the exact nature of the relationship is not known, it is not possible to determine with absolute confidence the points at which statistical significance can safely be assumed. Nonetheless, a test statistic, based on the standard test for equality of two proportions was calculated (e.g. Underhill and Bradfield 1996). The test statistic has, approximately, the standard normal distribution. Although there are caveats to the interpretation of reporting rates, and especially to interpreting differences between reporting rates (Harrison and Underhill 1997), this provides a first approach to interpreting whether a change in reporting rates is statistically significant, taking into account the numbers of checklists which are available. The statistic was calculated as follows

where P_1 and P_2 are the reporting rates from SABAP1 and SABAP2 respectively, n_1 and n_2 are the numbers of checklists on which the reporting rates are based, and P is the pooled reporting rate

These results are presented in graphic form, which aids interpretation and highlights areas of concern. The map uses a colour-coding system to classify the Z-score for each QDGC into one of six categories: $Z > 2.58$ (blue; important increase in reporting rate), $2.58 > Z > 1.64$ (dark-green; distinct increase in reporting rate), $1.64 > Z > 0$ (light-green; increase in reporting rate, but probably attributable to sampling variability), $0 \geq Z > -1.64$ (yellow; decrease in reporting rate, sampling variability), $-1.64 > Z > -2.58$ (orange; distinct decrease) and $Z < -2.58$ (red; important decrease). An additional category was created for QDGCs in which the species was recorded in SABAP1 but for which no checklists had yet been submitted for SABAP2; these QDGCs were shaded pink.

National population trend index

A method for modelling trends in the status of the Southern Black Korhaan population as a whole was developed. Previous assessments had been by precinct (e.g. Young et al. 2003) and no attempt had been made to combine them into an overall population index. Annual bird densities (birds/100 km) by precinct obtained from the CAR data using the Underhill index formed the basis of this approach. Five different sets of weights (described below) to be applied to these densities were developed and compared. This was done separately for summer and winter data. For the Eastern Cape Karoo and

Swartland precincts, which did not have data for winter 1997 or summer 1998, the density for the following year of surveys was applied to the year missing data. Once the weights had been applied, the resultant values were summed across precincts and the yearly totals were converted into an index, using 2010 as the base year, in which the index was set to 100.

The first choice was equal weights for each precinct, so the index values were based on a simple average of the densities for the precincts. The second set of weights was based on the area of each precinct. The area of a precinct was defined as the total area of all QDGCs which routes of that precinct entered. These areas were calculated using ArcView 3.1 and the set of weights, which must sum to one, was obtained by dividing the area for precinct by the total area covered by all the precincts included in the analysis.

The third set of weights was based on SABAP1 reporting rates. Densities of many bird species were shown by Griffioen (2001) to be well modelled by their reporting rates according to the relationship

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where is the estimated population density, is the observed reporting rate, and and are parameters to be estimated. Griffioen (2001) calculated estimates of the alpha and beta parameters for a large sample of Australian bird species. However, in the vast majority of cases the estimated value of was close to one, so the effect of the term was negligible. Because the aim of this analysis is not to calculate actual densities, only an index of density, it is sufficient that density is proportional to – , and not necessary to determine the value of . The third set of weights was used to test the importance of this conversion by using the simple reporting rates per precinct, standardised so they summed to one. Reporting rates were defined as for the SABAP comparison map, and precincts were defined as for the area weights.

To create the fourth set of weights, the reporting rates were multiplied by the areas and standardised. For the fifth set of weights, Griffioen's (2001) conversion was applied to the reporting rates and these values were multiplied by the areas and then standardised.

The size and importance of the portion of the species' range not covered by the CAR project was assessed. This provides a measure of the proportion of the population which was not included in the indexing process.

Results

CAR project

Population trends

Precincts that met the criteria for inclusion in this analysis were Overberg, Swartland and Eastern Cape Karoo (Figure 1 in Chapter 1). Overall 1 514 Southern Black Korhaans were recorded, in 14 (Overberg) or 13 years (Eastern Cape Karoo and Swartland) of surveys (Table 1). By far the largest number of birds was recorded in the Eastern Cape Karoo precinct (845 birds), with less than half of this number in each of the Overberg and Swartland precincts (395 and 274 birds respectively).

Populations of Southern Black Korhaans declined in the Overberg and Swartland precincts over the study period, but the species increased in numbers, after a period of decline, in the Eastern Cape Karoo precinct (Figure 3; Appendix 1, Table A1.1). Trends were strong, with R^2 values of over 0.60 for four data precincts: Eastern Cape Karoo summer, Overberg summer and winter and Swartland winter.

The Overberg population growth rate for both seasons was negative for all years except for 2009 and 2010 in summer, as was the Swartland population growth rate for the winter counts. The pattern in all three trajectories was similar: an initial brief period of relative stability, followed by a period of steep decline (more than 20% of the population lost per year for several years), and finally a period in which the population decline slowed. The large amount of noise in count totals for the first five years in the Swartland summer counts makes it difficult to detect a trend. The Eastern Cape Karoo figures showed a different pattern: an initial period of decline, which reversed in 2002–03, and in the last seven years of the series the population appeared to increase by c. 15% per year.

Analysis of the inflection points in the trends (Appendix 1, Table A1.1) suggested that periods of accelerating population decline ended in the Swartland precinct between 2007 and 2008 (using winter data only) and in the Overberg between 2005–06 (summer data) and 2008–09 (winter). Thereafter, although the populations may still have been declining, the rate of decline was decelerating. In the Eastern Cape Karoo, inflection points were at 2008–09 for summer and 2005–06 for winter; at these points the rate of population increase appears to have begun to decelerate.

Average densities of birds were similar in the two Western Cape precincts in both summer and winter; they were higher in winter than in summer for both precincts

(Overberg summer: 0.5 birds/100 km, SD 0.2; winter: 1.2 birds/100 km, SD 0.9; and Swartland summer: 0.6 birds/100 km, SD 0.4; winter: 1.7 birds/100 km, SD 1.2). Densities in the Eastern Cape Karoo precinct were two to four times those in the Western Cape and were higher in summer (summer: 4.0 birds/100 km, SD 1.5; winter: 2.5 birds/100 km, SD 1.7).

Habitat use

One additional precinct was included in this analysis: the Little Karoo. The habitat selection analysis indicated that the species selected for natural vegetation in all precincts and both seasons except in the Little Karoo in winter ($D = -0.17$; Table 2). The strongest selection was shown in the Swartland precinct ($D = 0.80$ for summer and 0.59 for winter), with the Eastern Cape Karoo precinct next ($D = 0.33$ for summer and 0.63 for winter). Despite their preference for transformed land in the winter in the Little Karoo precinct, the birds' preference for natural habitat in that precinct in the summer was relatively strong ($D = 0.50$). The birds in the Overberg showed a moderate preference for natural habitat ($D = 0.36$ in summer and 0.24 in winter). Sign tests indicated that although there was a greater number of routes on which the birds showed a preference for natural habitat in all cases, this was significant only in the Eastern Cape Karoo (summer, $p < 0.001$, and winter, $p < 0.01$) and the Swartland (summer, $p < 0.05$) precincts.

The majority of Southern Black Korhaans which were seen on CAR surveys were recorded as being in natural vegetation ("veld") in all precincts except Overberg and in the Swartland in summer (Figure 4). More than 95% of birds were seen in natural habitats in the Eastern Cape Karoo precinct. Approximately 30% were seen in natural vegetation in the Overberg precinct, and 48% in the Swartland in summer. Important transformed habitats (i.e. more than 10% of birds were seen therein) were crop stubbles (all three Western Cape precincts), pastures (Overberg and Little Karoo), fallow land and crop fields (Swartland) in the summer, and crop fields (all three Western Cape precincts) and pastures (Overberg) in winter.

SABAP data

Occupancy modelling

The optimal-fit occupancy model across the Southern Black Korhaan's range, according to Akaike's information criterion (AIC), estimated occupancy probability as a function of biome, with Succulent Karoo kept separate, Albany Thicket and Fynbos added together, and the rest of the area (essentially Nama Karoo) lumped together (Table 3). It estimated detection probability as a function of season and biome, with Albany Thicket and Fynbos kept separate and the other biomes lumped together for SABAP1 and Albany Thicket and Succulent Karoo kept separate and the remaining area lumped together for SABAP2. The second covariate, percentage of QDGC anthropogenically altered, did not improve the model; nor did estimating colonisation and local extinction probabilities separately for different biomes.

Occupancy probability estimates decreased from SABAP1 to SABAP2 for two biomes, as did detection probability in all biomes except Albany Thicket (Tables 3 and 4). The probability that a QDGC was occupied by Southern Black Korhaans during 1987–1992 (SABAP1) was estimated as 0.72 for the Albany Thicket and Fynbos biomes, and this decreased by 30%, to 0.50 in the SABAP2 period ($p = 0.061$). In the Nama Karoo the occupancy probability remained unchanged at 0.3. The decrease for the area as a whole was calculated as the decrease for each biome multiplied by the percentage of the whole area that biome represented, and came to 23.5% ($p < 0.001$).

The estimated probability of local extinction in a QDGC (0.36) was more than double the probability of colonisation of a QDGC (0.15). Estimates of detection probabilities were low for all biomes, but increased for the Albany Thicket biome from 0.15 for SABAP1 to 0.21 for SABAP2 ($p < 0.001$). Detection probabilities for the rest of the area decreased by between 40% and 67%: from 0.29 to 0.17 for the Succulent Karoo ($p < 0.001$) and 0.10 for the Nama Karoo ($p < 0.001$), and from 0.24 to 0.10 for the Fynbos ($p < 0.05$).

SABAP comparison map

Reporting rates for Southern Black Korhaans decreased in 226 out of the 284 QDGCs in which the species was reported in either SABAP1 or SABAP2 (Figure 5; red, orange and yellow QDGCs). The Western Cape part of the range had the largest proportion of QDGCs showing a decline in reporting rates (86%), followed by the Northern Cape (73%) and then the Eastern Cape (71%). The majority of important declines (red and orange QDGCs) were in the Western Cape (79 QDGCs, compared with four in the Northern Cape and 15 in the Eastern Cape). QDGCs in which increased reporting rates were observed (light green, dark green and blue) were scattered in the Northern and Western Cape parts of the species' range, and were only contiguous to a small extent in the Eastern Cape. In contrast, areas of decreased reporting rates were largely contiguous (Figure 5).

National population index

The three sets of weights incorporating area increased the weight of the Eastern Cape Karoo precinct to 0.53 (area only) or 0.45 (reporting rate only) or 0.64–0.66 (area and reporting rate) and decreased the weight of the Swartland precinct to 0.19 (area only) or 0.11–0.12 (area and reporting rate; Appendix 1, Table A1.3). The Overberg precinct's weight decreased slightly for all weights incorporating area (0.23–0.28) and was close to neutral for the weights involving reporting rate only (0.32). The two sets of weights incorporating both area and reporting rate differed by only 0.02 for Eastern Cape Karoo and 0.01 for Overberg and Swartland.

The different weights affected the winter national population indices more than those created using the summer data (Figure 6; Appendix 1, Table A1.4). All indices incorporating area produced lower index values for 1998–2004 for the summer data and 1997–2005 for the winter data, with the lowest values being those weighted by both area and reporting rate. The discrepancy between the values was greater for the winter data. Summer and winter trends were contradictory. Summer indices suggested that the Southern Black Korhaan population increased by c. 40% after a seven year period during which the population was between 35% and 70% of the 2010 level. Winter indices incorporating area and reporting rate in the weighting suggested that the population was at approximately the 2010 level in 1997, but after four years at about this level it decreased to c. 20% of this level in 2002, after which it increased to c. 150% of this level in 2005–06. It then decreased to c. 70% of the 2010 level in 2007, and increased once more until 2010.

The proportion of the range covered by the CAR precincts included in this analysis was c. 34%. The portion of the range not covered was mainly in the Western and Northern Cape provinces, in the Succulent Karoo and Fynbos biomes.

Discussion

CAR data

Population trends

There is little doubt that, between 1997 and 2010, the Southern Black Korhaan decreased in abundance in parts of its range (Overberg and Swartland), while it may have increased somewhat in the Eastern Cape Karoo region (Figure 3). The species declined dramatically in abundance in the best-known Overberg and Swartland precincts from 1997 to 2008. The apparent rate of population decline slowed in 2008–09, with the relevant inflection points occurring between 2004 and 2009. These inflection points may have been related to the species reaching its new lower carrying capacity, based on the area of suitable habitat that was then available to it. The rate of population increase in the Eastern Cape Karoo precinct began to decrease between 2005 and 2009, which may indicate that in that area, too, the species was reaching equilibrium with its environment. If these inflection points reflect the population reaching carrying capacity, the processes that would cause the change in a decreasing trend would be, for example, a gradual increase in the proportion of birds able to find suitable territories, or an increase in breeding success. These increases would theoretically occur over several years until the population had stabilised, at which point, barring other disturbances, they would remain constant.

Southern Black Korhaans are typically shy and prefer bushy habitats, at least in the fynbos parts of their range, so their overall detectability is low. The females are highly cryptic and are often seen only when flushed. Males are boldly coloured and thus more easily detected, especially when calling, which they do at highest frequency during the breeding season (Allan 2005b). The Southern Black Korhaan's breeding season is timed according to seasonal rainfall (Young et al. 2003), and is thus earlier in the winter rainfall regions of the Western Cape (egg-laying takes place from late winter to late spring) than in the mixed and summer rainfall regions of the Eastern Cape (egg-laying from late spring to summer; Allan 2005b). Winter CAR count totals can thus be expected to be larger and probably more reliable than summer totals in the Western Cape, and vice versa in the Eastern Cape (Young et al. 2003). This is borne out by the data.

The higher density of birds in the Eastern Cape Karoo precinct is probably explained largely by the fact that land use and transformation are significantly less intensive in this region; the majority of privately owned land was natural veld used for grazing. However, since karoo vegetation is typically low and open, korhaans are likely to be more detectable there, so the higher apparent density may be partly an artefact of greater detectability.

Habitat use

The analysis of habitat selection in well-covered parts of the species' range demonstrated that Southern Black Korhaans showed some preference for natural habitats over transformed land. This preference, however, was not as strong as expected, particularly in the Overberg precinct, and it appeared that birds did make substantial use of altered habitats extent in this region. However, a Southern Black

Korhaan is likely to be more conspicuous in a ploughed field than in shrubby fynbos vegetation. The magnitude of the bias, if any, is unknown, and is presumably reduced by the fact that birds only had to be heard calling to be recorded. This is an issue that needs to be addressed by further fieldwork.

Due to important differences between the habitat categories used in the NLC (habitat availability) and CAR (habitat use) data, it was not possible to analyse the Southern Black Korhaans' habitat preferences in more detail. Habitat categories used in the CAR project were those thought to be most relevant to the birds using them, e.g. fallow, crop stubble, pasture, crop type, etc. The NLC data were derived largely from satellite images and were intended to be valid and useful for a period of several years, and thus did not include these types of categories. The fact that CAR project participants did not collect detailed habitat availability data is a major shortcoming of the CAR project data; if participants had recorded this information then habitat selection could be studied in more detail. However, this amount of extra data collection is likely to deter a substantial proportion of the participants from taking part, so this is therefore part of the necessary trade-off between the great benefits of using citizen scientists to collect large quantities of data that it would otherwise not be possible to collect, and obtaining high precision data.

CAR project data have enabled us to confirm that Southern Black Korhaans do use farmland where little else is available (especially in the Overberg, where c. 80% of land is transformed), but that in general they prefer natural veld. The seasonal differences in the use of transformed habitats probably reflect seasonal changes in availability of stubble and crop fields.

SABAP data

Occupancy modelling

Occupancy modelling of SABAP data confirmed that the Southern Black Korhaan was most common in the Fynbos, Albany Thicket and Succulent Karoo biomes, and less so in the Nama Karoo biome, of which it occupied only a small portion in the extreme south. Albany Thicket was only described as a biome after 1994 (Mucina and Rutherford 2006), and was therefore not mentioned in Crowe et al.'s (1994) analysis of the species' habitat preferences. However, the inclusion of this biome in the model fitted well with their statement that this korhaan prefers shrubby habitat in winter- and mixed-rainfall areas (Crowe et al. 1994). The best fitting occupancy model across the Southern Black Korhaan's range (according to AIC) further supported the conclusion that in most of its range the species declined in abundance between the data collection phases of SABAP1 and SABAP2. The estimated probability of occupancy of QDGCs decreased significantly over the species' range as a whole. This implies that the species' range had shrunk, as the number of QDGCs in which it occurred had decreased.

The significant decrease in detection probabilities in all biomes except Albany Thicket was unlikely to have been caused by anything other than declining abundance. Other factors that can influence detection are seasonal behaviour and plumage changes, changes in vegetation structure, and changes in observers and the observation process. Seasonal plumage changes do not apply to this species, and while the effect of seasonal behaviour changes are obvious in the CAR data, they cannot be a factor when comparing two datasets each spanning several years and covering all seasons.

Although the observers surely changed to some extent from SABAP1 to SABAP2, when so many observers were involved in both projects it is extremely unlikely that the combined effect of all the differences in individual levels of skill would lead to so marked and consistent a decline in detection for this species. If anything, the skills and effort invested in data collection can be expected to have increased in this time. Although it is possible that the changes in atlasing protocol could bias the results of these models for species with very limited ranges and high habitat specificity, under very specific conditions (e.g. African Penguin as suggested in Ryan 2011), this is unlikely to be the case with a species such as the Southern Black Korhaan. This species occurs in several widespread habitats over a large area, much of which was well covered by both atlas projects. In addition, SABAP comparison maps, which give a less nuanced visual representation of the changes in reporting rates between the two projects, also do not appear to be biased in any particular direction, and are generally consistent with prior knowledge about changes in species' ranges and abundance levels.

Finally, although vegetation structure may have changed between the SABAP1 and SABAP2 observation periods, it is unlikely to have changed in any systematic way apart from through land transformation. If anything, in some areas it may have changed such that birds would be more visible rather than less so, as natural veld was increasingly converted to agriculture. A general increase in the woody component of vegetation, ascribed mainly to the global increase in atmospheric carbon dioxide levels, has been observed over the last 50–100 years in a range of vegetation types around the world (Sirami et al. 2009). However, this is unlikely to have affected the entire range of the Southern Black Korhaan so uniformly over 15–20 years as to cause a widespread decrease in detection probabilities of this magnitude. Changes of this nature are unlikely to have been sufficiently dramatic in all biomes over the study period to have had this effect, because the Fynbos biome, particularly renosterveld, already had a substantial woody component, and the Succulent Karoo is semi-arid and water is therefore likely to be the principal limiting factor, rather than carbon dioxide. If this were a factor influencing detectability, one would expect to see a similar effect for all similar sized birds in these biomes, but an examination of the SABAP comparison maps for some such species (e.g. Chapter 6) showed that this was not the case. Therefore although it is possible that change in vegetation structure may have had some minor effect on the detectability of Southern Black Korhaans, it is highly unlikely that it was responsible for this significant decrease in detectability in three of the four biomes in which the species occurs.

The increase in detectability in the Albany Thicket biome fits well with the increase in numbers of birds seen in the Eastern Cape Karoo precinct in CAR counts, and was unlikely to be due to change in vegetation structure since almost all the birds seen in this precinct (c. 97%, Appendix 1, Table A1.2) were seen in natural veld. The largest and most consistent increases in the CAR count totals, however, were observed on routes that were almost exclusively in karoo vegetation rather than thicket (Mucina and Rutherford 2006). Since the Albany Thicket biome intergrades with both the Succulent and Nama Karoo biomes in this region, the increase in detectability assigned to the former biome by the best fitting occupancy model may actually have occurred in the karoo areas, but because it only occurred in this part of the Southern Black Korhaan's range, it was more closely correlated with the occurrence of Albany Thicket than karoo.

It is likely that the relationship between detection probability and abundance is similar to that between atlas reporting rates and population density, and a 60% decline in detection probability does not necessarily imply a 60% decline in density. However, the relationship between reporting rates and population density proposed by Griffioen (2001) and used to create one of the national population indices is approximately linear for reporting rates between zero and 60%. Above this reporting rates increase more slowly for larger and larger increases in density. Out of a total of 275 QDGC where Southern Black Korhaans were recorded in either SABAP1 or SABAP2, only 26 have reporting rates above 60% for either or both of the atlas projects (Figure 5). The linear relationship between reporting rate and density can therefore be assumed to hold for the majority of the range. If this is the case, and if detection probability is similarly related to abundance, then a 60% decline in detection probably is likely to imply a similar decline in abundance.

SABAP comparison map

The SABAP comparison map provides strong visual confirmation of the findings of both the population trends produced from CAR project data, and the occupancy modelling of SABAP data. Over the majority of its range, reporting rates for the Southern Black Korhaan declined between the SABAP1 and SABAP2 data collection periods. The region in which this was most significant and severe was the Overberg–Swartland region. In the Western Cape 37 out of 158 QDGCs show reporting rates that decreased from more than 30% to less than 10%, and 15 in which it decreased from above 50% to less than 20%, including 7 in which it had dropped from above 50% to zero. If the relationship proposed by Griffioen (2001) holds, this represents a large and widespread decrease in abundance, mitigated only by a possible increase in abundance in a small number of scattered QDGCs in the Eastern Cape.

There were some QDGCs around the edges of the species' range where the reporting rates for SABAP2 were higher than for SABAP1. Although these grid cells could represent a slight range expansion, it is more likely that this phenomenon is an artefact of the change in protocol from SABAP1 to SABAP2. While SABAP2 operated at a 5' by 5' resolution and required participants to attempt to cover all habitats within a pentad, SABAP1 operated at a 15' by 15' resolution and made no such stipulation. Thus in SABAP1 many QDGCs were surveyed primarily along main roads and in other easily accessible places. Habitats that did not intersect those places and species that tend to avoid main roads and human disturbance (of which the Southern Black Korhaan is one) may therefore have been missed entirely. Thus not only would slight apparent range expansions observed in SABAP2 be likely to be an artefact of the new protocol, but any range contractions observed are likely to be more severe than the data suggest.

National population index

The national population index for this species was contradictory for summer and winter. It is not clear whether this is of biological significance or if it is an artefact of noise in the data. The index was based on data collected in about one-third of the species' range. Should this species prove to be occasionally nomadic, and local abundance change rapidly with changing conditions, as is the case with the Northern Black Korhaan (Allan 1997), it is possible that that the seemingly contradictory values are a consequence of differential movement in response to rains in successive years. However, it seems more likely that they are a consequence of outliers in the Eastern Cape Karoo CAR data in particular (Figure 3). This precinct was heavily weighted because of its relatively large area and the relatively high SABAP1 reporting rates for the species (Appendix 1, Table A1.3). The SABAP comparison map (Figure 5) shows that the area in which reporting rates increased from SABAP1 to SABAP2 was a small proportion of the range as a whole. An improved national population index, therefore, is dependent on CAR routes being established throughout the range of the species.

General

Although a relatively large bird, the Southern Black Korhaan is retiring and, in females, well camouflaged, and therefore easy to miss. While many of the people involved in the CAR project who lived within the species' range were already aware that it seemed to be decreasing in numbers, neither the birding community in general nor the ornithological community appeared to have noticed a decline. This is likely to be at least in part due to its close relative the Northern Black Korhaan being an abundant species, and the fact that until recently the two species were considered one.

Although public participation surveys necessarily involve some compromises in terms of the scientific quality of the data (e.g. Cohn 2008, Silvertown 2009), when enough data are gathered, and especially when two different projects can be used to gain two different angles on the same problem, the data can provide conclusions of great worth. The fact that two projects with different protocols and aims have provided data which present such similar pictures, which are moreover backed up by plentiful anecdotal evidence, gives weight to the contention that a real population decline is well underway.

It is likely that this decline has come about because of a decrease in suitable breeding territories, caused by habitat destruction, and decreased breeding success, caused by increased disturbance related to farming activities and increased chick and egg predation because of a general decrease in cover and an increase in predators such as crows (SABAP2, unpubl. data). Adults may also have suffered increased predation rates and even increased starvation because of the decline in cover and suitable habitat. However, further field-based study is urgently required to confirm the biological mechanisms of the decline.

It is difficult and often impractical to try and change the design or protocol of citizen science projects once they are well established, especially if this requires more time and effort from the volunteers, and where volunteer numbers are limiting, as in the CAR project. However, the following changes to the design of the CAR project would be desirable:

- Participants should collect basic habitat availability data all along the length of each route, every time it is surveyed, to allow calculation of detailed habitat preferences.
- More routes should be set up to better cover the full range of the Southern Black Korhaan, especially in the sections of its range in the Northern Cape and the remaining sections of the Western Cape.
- Little Karoo and Eastern Cape precincts should if possible be covered more consistently to improve data quality and comparability.
- Existing routes should be changed as little as possible in future. Changing routes, unless the changes are small, means that the new route cannot be assumed to be equivalent to the old route, which greatly complicates data analysis.

A more pragmatic recommendation would be to incorporate data on Southern Black Korhaan activity and side of the road seen on (as is collected for the three crane species and the bustards).

A recommendation for SABAP2 is to encourage participants to increase their coverage of the Northern and Eastern Cape sections of the Southern Black Korhaan's range. A publicity drive and call for information on this species is also highly recommended.

Further research is needed to gain a more accurate population estimate, information on seasonal habitat use, movements (if any), and current threats. We assume that loss of natural habitat constitutes the primary threat to this species, as postulated by Allan (1997, 2005), but it is also possible that climate change and predation (probably of eggs and chicks) by predators such as crows may be accelerating the species' decline. It has been suggested that many of the observed declines in populations of European farmland birds may have been caused by an interaction between land-use change and predation, and high on the list of predators suspected of causing declines are corvids (Evans 2004). In South Africa, Pied Crows *Corvus albus* have been observed preying upon nests of Blue Cranes *Anthropoides paradiseus*, and Black Crows *C. capensis* are thought to prey upon nests of Karoo Korhaans *Eupodotis vigorsii* (Bidwell 2004).

Useful future research would be to conduct a large number of repeated surveys of selected areas in which the birds are known to occur (both CAR and SABAP surveys). This would increase the precision of population, occupancy and detectability estimates for those areas, and would allow enhanced interpretation of data from both projects for other areas.

Conclusions

Our analyses illustrate how data from public participation surveys can be used together to identify population changes in a species which might otherwise have gone unnoticed. This highlights both the great value of well planned and organised long term public participation surveys, and the importance of developing appropriate techniques for data analysis. It is our hope that these methods will be adapted to other such integrated analyses of multiple spatial datasets.

The data and analyses presented here constitute convincing evidence that the population of the Southern Black Korhaan declined overall between 1992 and 2010, although the decline may have decelerated from 2008 onwards. This species now appears more vulnerable to environmental change, including further land transformation, than when the CAR project began in surveying it in 1997. We recommend therefore that the species be considered for listing on the IUCN Red List with a threat category of Vulnerable (VU) under criteria A4: a suspected reduction in population size of at least 30% over a three generation period, past and future, where the reduction or its causes may not have ceased, are not fully understood and may not be reversible, based on (b) an index of abundance appropriate to the species and (c) a decline in area of occupancy and quality of habitat (IUCN 2001).

It is not known how long a generation period for this species is; the age at first breeding for females is likely to be one or two years (Collar 1996), but the IUCN criteria define a generation period as the average age of parents of the current cohort, i.e. it should "reflect the turnover rate of breeding individuals in a population". The longevity of this species is not known, so that age cannot be calculated, but we believe that the generation period is at least five years. If so, the present study covers approximately three generations, and we suspect that the Southern Black Korhaan population declined by at least 30% over the study period, and that it will continue to decline in parts of its range if the conversion of natural vegetation to agriculture continues.

Climate change is likely to aggravate the threat of habitat loss, and predation by predators such as Pied Crows, which have increased in abundance over the study period (SABAP2, unpubl. data) is a further aggravating factor. It is now necessary for a more detailed study to be conducted, with the aim of improving our understanding of the status of the population, the causes of its decline, and any possible mitigation measures that may be taken.

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Table 1: Summary of population trend analysis data for the Southern Black Korhaan from the Coordinated Avifaunal Roadcounts (CAR) project. The column "Number of routes" gives the number of routes surveyed at least six times in either summer or winter. Average route lengths were calculated from these routes. "Number of years" gives the longest series used in the analysis. "Start year" gives the earliest year from which data were used for this analysis. "Total Southern Black Korhaans" gives the total number of birds seen in these precincts on all routes and in both summer and winter, from the first year in which the precinct was surveyed until 2010 inclusive. Figures are only included for analysed precincts, even though small numbers of birds may have been recorded in other precincts.

Precinct	Number of routes	Ave. route length (km)	Start year	Number of years	Total Southern Black Korhaans
Eastern Cape Karoo	20	57.7	1998	13	845
Overberg	33	54.7	1997	14	395
Swartland	16	61.3	1998	13	274
Total	69	57.1			1 514

Table 2: Habitat selection analysis of Southern Black Korhaan CAR data for the Overberg, Swartland, Eastern Cape Karoo and Little Karoo precincts, summer (S) and winter (W) counts. Jacobs index D values indicate selection for natural habitat if positive, and for transformed land if negative. Numbers in the Natural and Transformed columns are the numbers of routes on which a preference was shown for natural and transformed habitats respectively. Sign test p values refer to tests of whether the number of routes with positive Jacobs index D values was significantly different from that expected if zero selection had been shown.

Precinct	Season	Jacobs index D	Natural	Transformed	Sign test p value
Eastern Cape Karoo	**S**	0.322	16	2	0.001
	W	0.626	15	2	0.002
Little Karoo	**S**	0.450	6	2	0.157
	W	–0.231	4	3	0.706
Overberg	**S**	0.346	11	6	0.225
	W	0.212	12	7	0.251
Swartland	**S**	0.793	9	1	0.011
	W	0.575	6	4	0.527

Table 3: Estimated and derived parameters from the best-fitting occupancy model for Southern Black Korhaans. A "1" in the parameter name indicates that an estimate applies to SABAP1, and a "2" that it applies to SABAP2. The Occupancy2 probabilities were derived from the estimated parameters using the formula Occupancy2 = Occupancy1 + Colonisation – Local extinction. The only biome in the area for which this model was constructed, but without a specific estimate attached to it, is the Nama Karoo. The columns labelled "95% upper" and "95% lower" give the 95% upper and lower confidence intervals respectively for each estimate.

Parameter	Biome	Estimate	SE	95% lower	95% upper
Occupancy1	**Albany Thicket + Fynbos**	0.718	0.035	0.644	0.782
Occupancy1	**Succulent Karoo**	0.608	0.060	0.486	0.717
Occupancy1	**others**	0.309	0.056	0.211	0.428
Colonisation	**all**	0.146	0.039	0.085	0.239
Local extinction	**all**	0.357	0.044	0.277	0.446
Occupancy2	**Albany Thicket + Fynbos**	0.503	0.037	0.430	0.576
Occupancy2	**Succulent Karoo**	0.448	0.042	0.366	0.530
Occupancy2	**others**	0.300	0.041	0.220	0.380
Detection1	**Albany Thicket**	0.152	0.009	0.135	0.170
Detection1	**Fynbos**	0.243	0.006	0.232	0.255
Detection1	**others**	0.289	0.011	0.268	0.310
Detection2	**Albany Thicket**	0.206	0.024	0.164	0.256
Detection2	**Succulent Karoo**	0.173	0.019	0.140	0.213
Detection2	**others**	0.095	0.005	0.085	0.106

Table 4: Changes in occupancy and detection probability estimates for Southern Black Korhaans from SABAP1 to SABAP2, expressed as percentages of the SABAP1 estimate value, and the p values derived from LRT testing of the models together with statistical significance indicators: ns = not significant; * = $p < 0.05$; *** = $p < 0.001$. The percent changes in estimates for the whole area were calculated using the percentage of the whole area in each biome, which is shown in the "% area" column.

Biome	Occupancy	*p*	Signif	Detection	*p*	Signif	% area
Albany Thicket	–29.98%	0.0606	ns	+36.06%	0.0000	***	12.66
Fynbos	–29.98%	0.0606	ns	–60.82%	0.0131	*	39.61
Succulent Karoo	–26.29%	0.8415	ns	–40.00%	0.0003	***	27.28
Nama Karoo	–2.99%	0.4839	ns	–67.00%	0.0000	***	20.45
Whole area	–23.45%	0.0000	***	–48.44%	0.0000	***	100.00

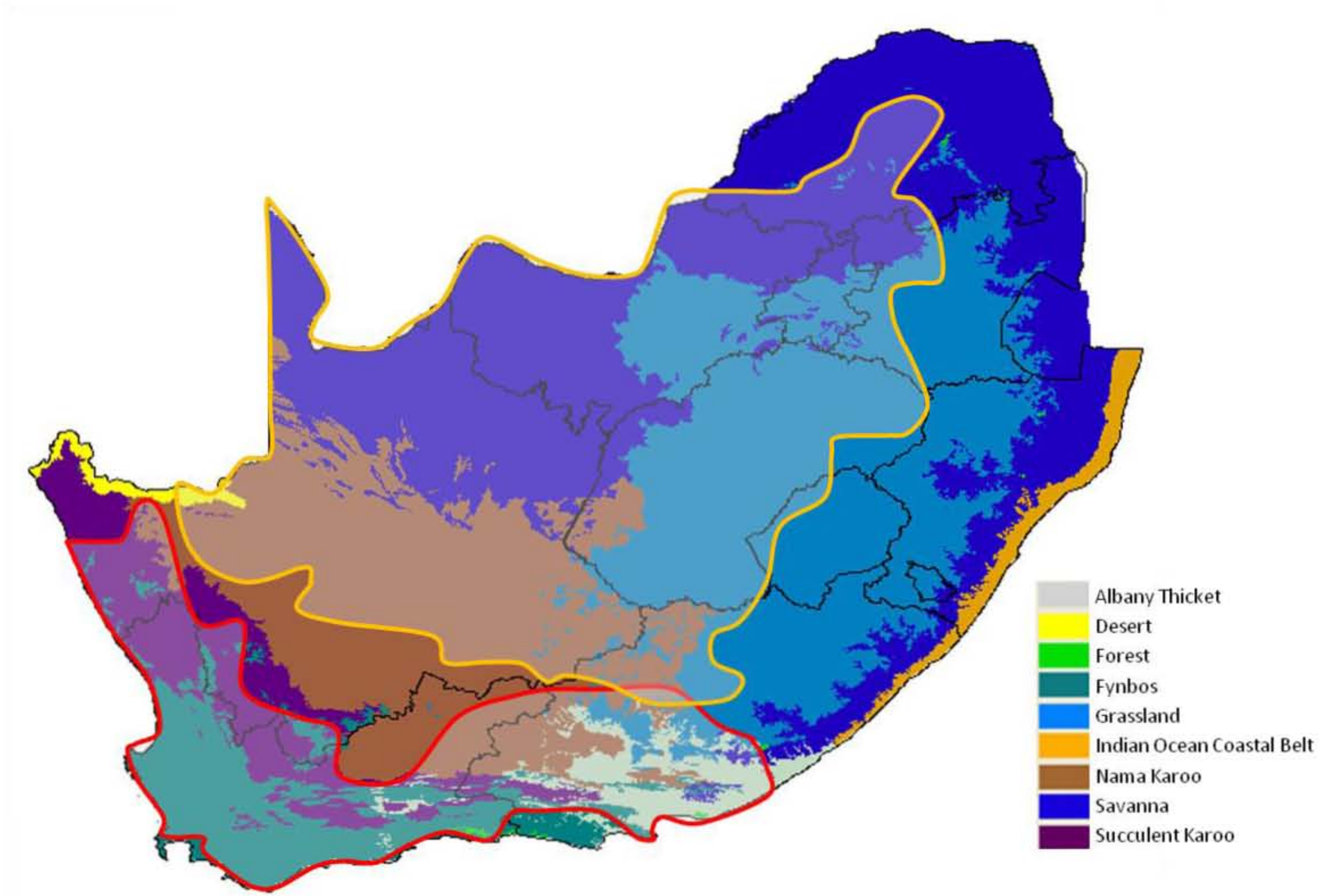

Figure 1a: Biomes (Mucina and Rutherford 2006) and outlines of the ranges of the Southern (red line) and Northern (yellow line) Black Korhaans, drawn using range maps produced using data from SABAP1 (Allan 1997) and SABAP2 (presented below).

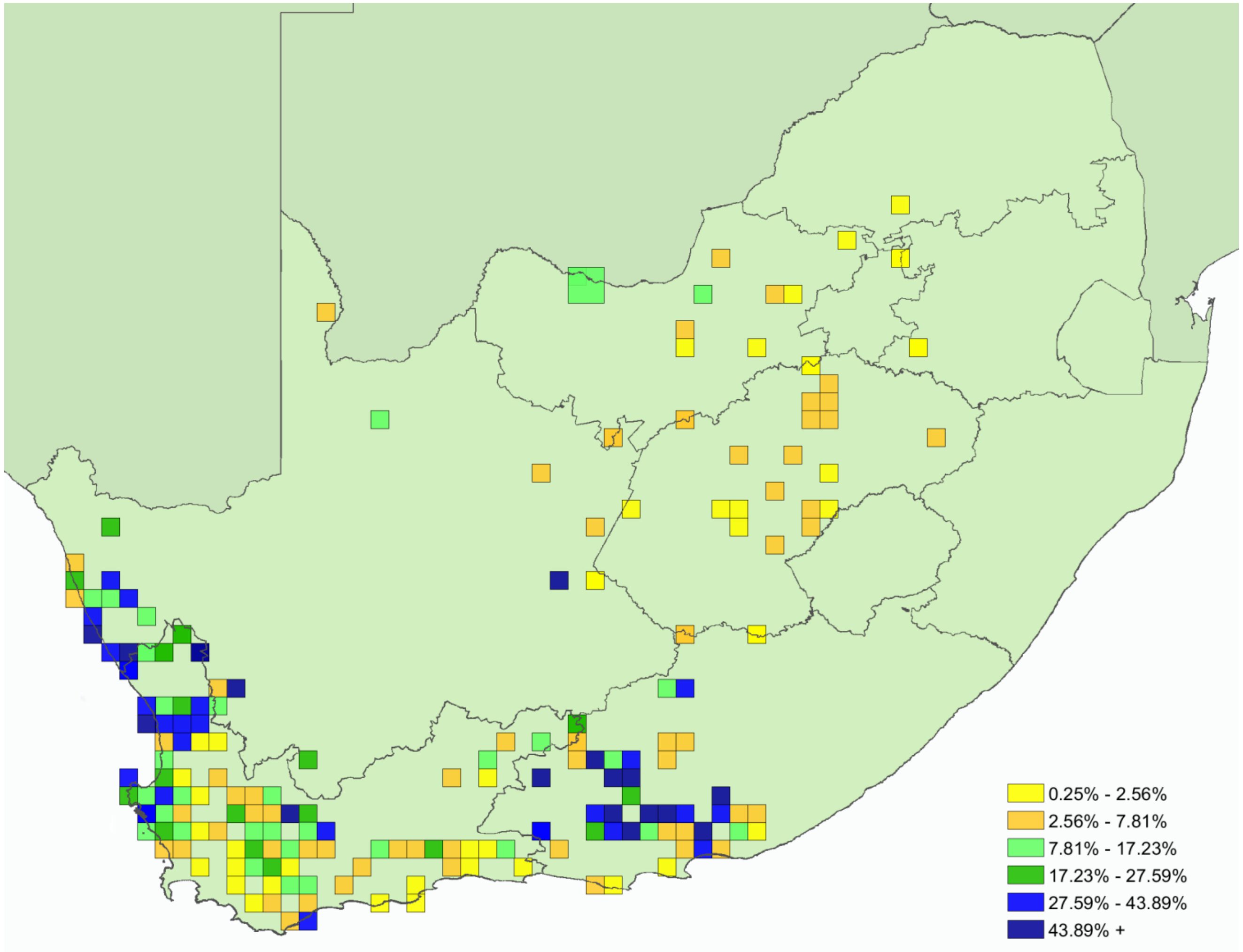

Figure 1b: Range map for the Southern Black Korhaan showing derived reporting rates calculated from SABAP1 and SABAP2 data, extracted on 10 February 2012. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15'). Derived reporting rates were calculated as described in Chapter 1. Coloured QDGCs within the range of the Northern Black Korhaan (Figure 1a) are an artefact of the complication of data vetting for species that were split since 1992 and should be ignored.

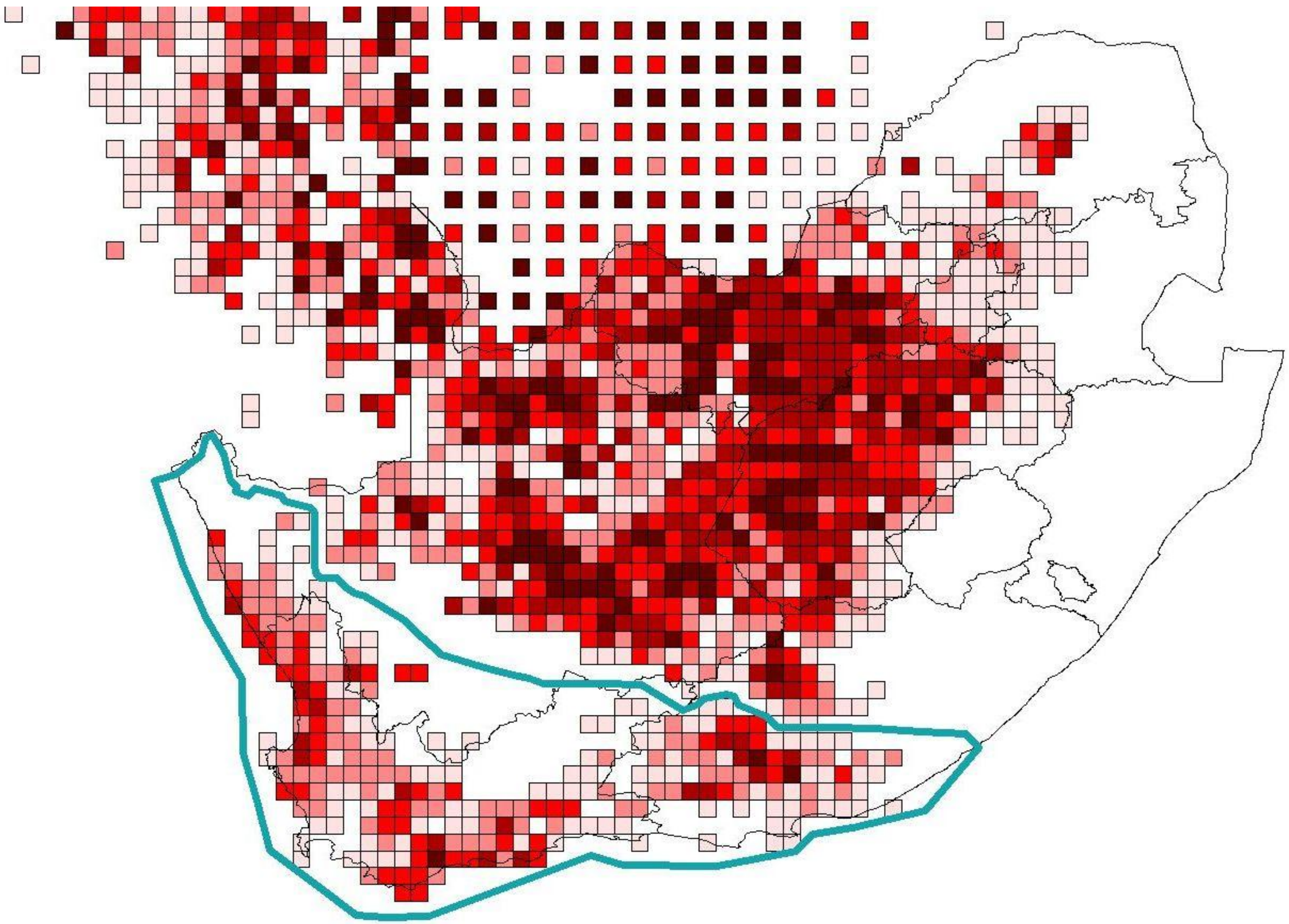

Figure 2: Data from the first Southern African Bird Atlas Project (SABAP1; Allan 1997) for the Black Korhaan, which was later split into the Southern and Northern Black Korhaans. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15'). Grid cells are shaded according to relative SABAP1 reporting rate: darker grid cells had higher reporting rates. The thick blue line encloses the Southern Black Korhaan data; all other data are regarded as Northern Black Korhaan. Data from within the outlined area were extracted from both SABAP1 and SABAP2 and used to model the probabilities of detection and site occupancy for Southern Black Korhaans.

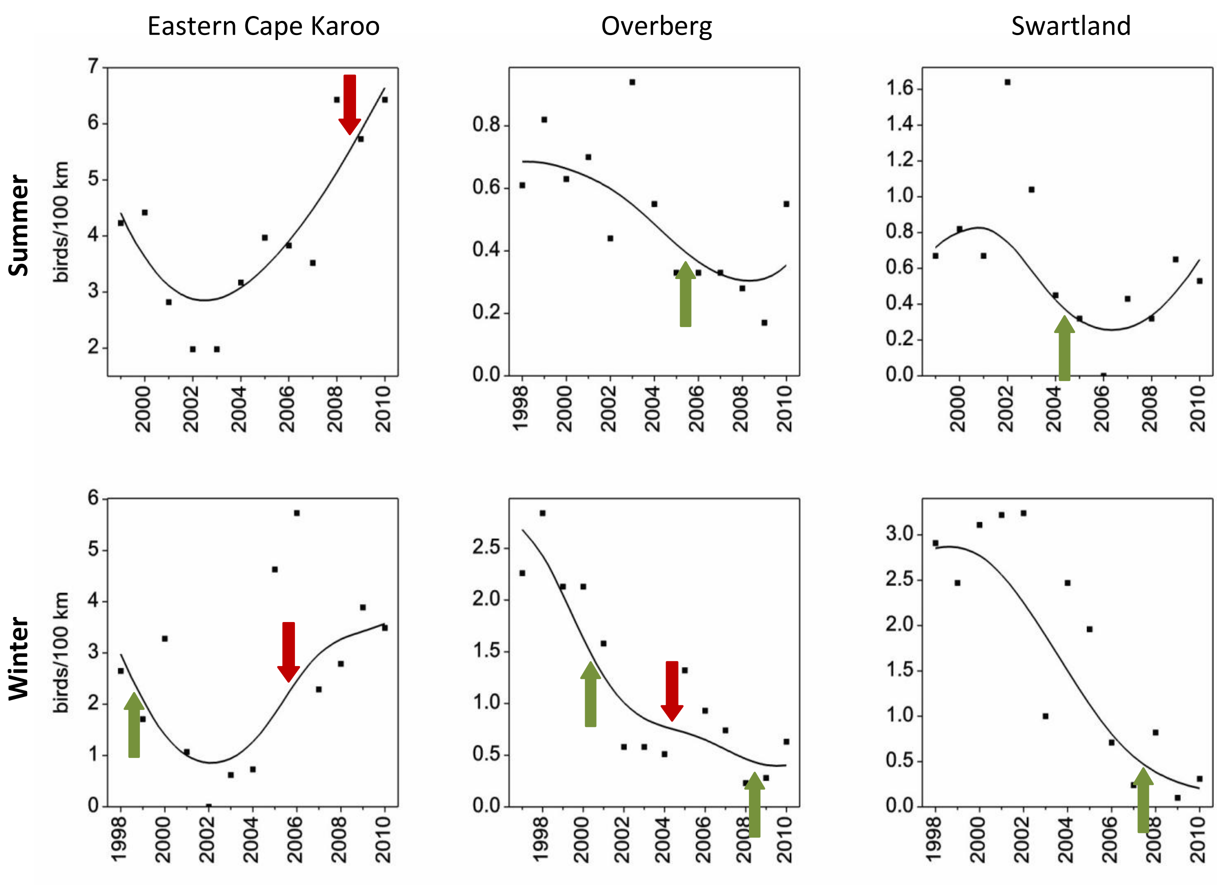

Figure 3: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Southern Black Korhaan for the Eastern Cape Karoo (summer: 1 063 km; winter: 1 155 km), Overberg (summer: 1 806 km; winter: 1 757 km) and Swartland (summer: 938 km; winter: 980 km) precincts (Figure 1 in Chapter 1) for summer and winter counts. Arrows indicate points of inflection in the trends; green arrows indicate where the rate of change went from negative to positive, and red the reverse.

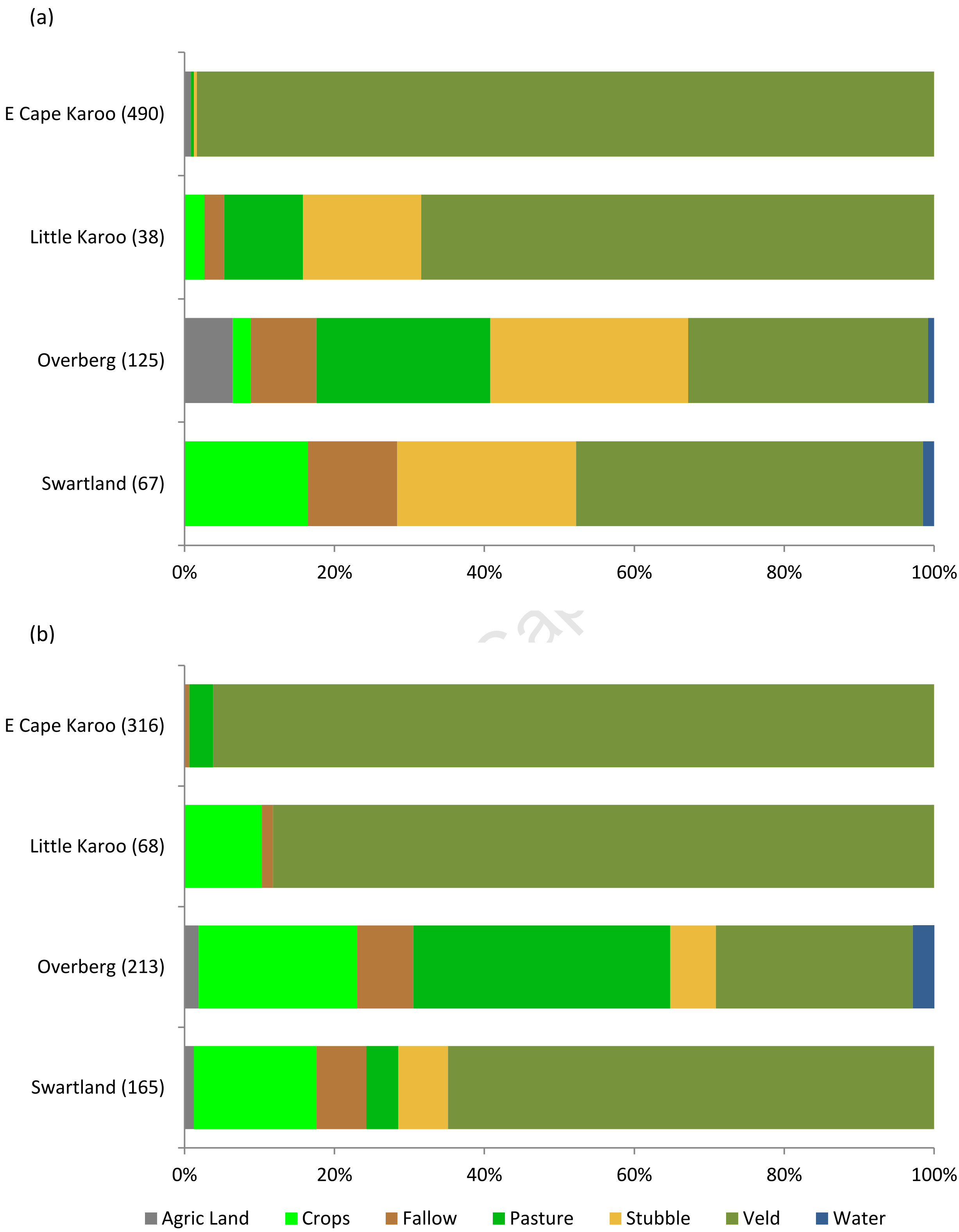

Figure 4: CAR habitat use data for Southern Black Korhaans for (a) summer and (b) winter counts, for the four precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in surveys conducted in that season. "Agric Land" includes ploughed land, mown land and other miscellaneous types of farmland; "stubble" indicates harvested crop fields, and "crops" includes all cultivated crops, orchards and vineyards.

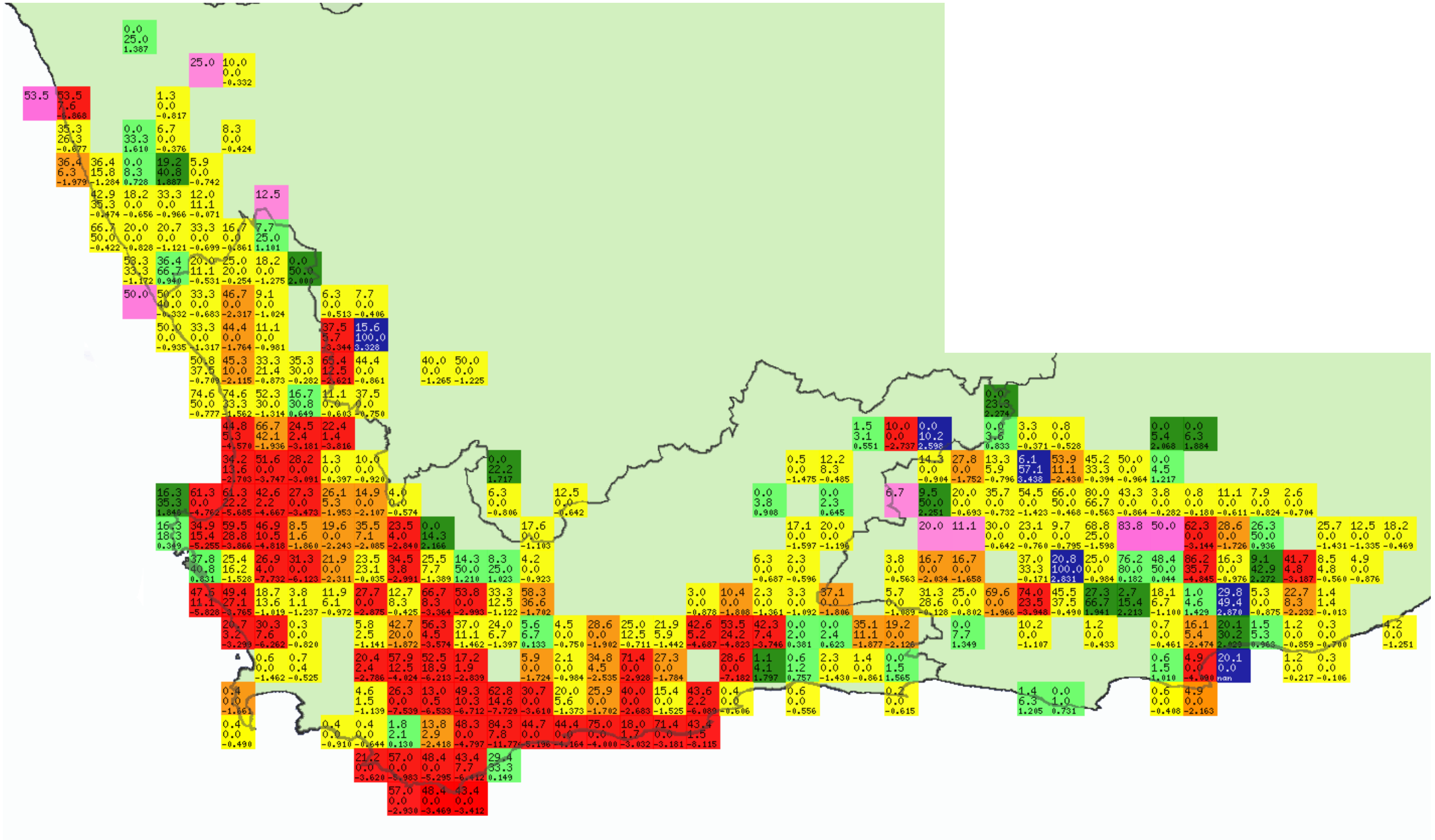

Figure 5: SABAP comparison map for the Southern Black Korhaan, extracted on 10 February 2012, showing the range of the Southern Black Korhaan only; data for the Northern Black Korhaan have been deleted. This map compares SABAP1 and SABAP2 reporting rates. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15') in which the species was observed in either project. Reporting rates are compared using the Z statistic (see text). The upper number in each square is the SABAP1 reporting rate, the middle number is the SABAP2 reporting rate, and the lower number is Z. SABAP2 reporting rates for were lower than SABAP1 in red, orange and yellow grid cells, and higher than SABAP1 for light and dark green and blue grid cells. In red grid cells $Z < -2.58$, in orange $-2.58 < Z < -1.64$, and in yellow $-1.64 < Z < 0$. In light green grid cells $0 \leq Z < 1.64$, in dark green $1.64 < Z < 2.58$, and in blue grid cells $Z > 2.58$. Pink grid cells are those which had not yet been covered in SABAP2. Therefore, red, orange and yellow grid cells indicate areas of potential conservation concern, whereas green and blue grid cells indicate areas of apparent population increase.

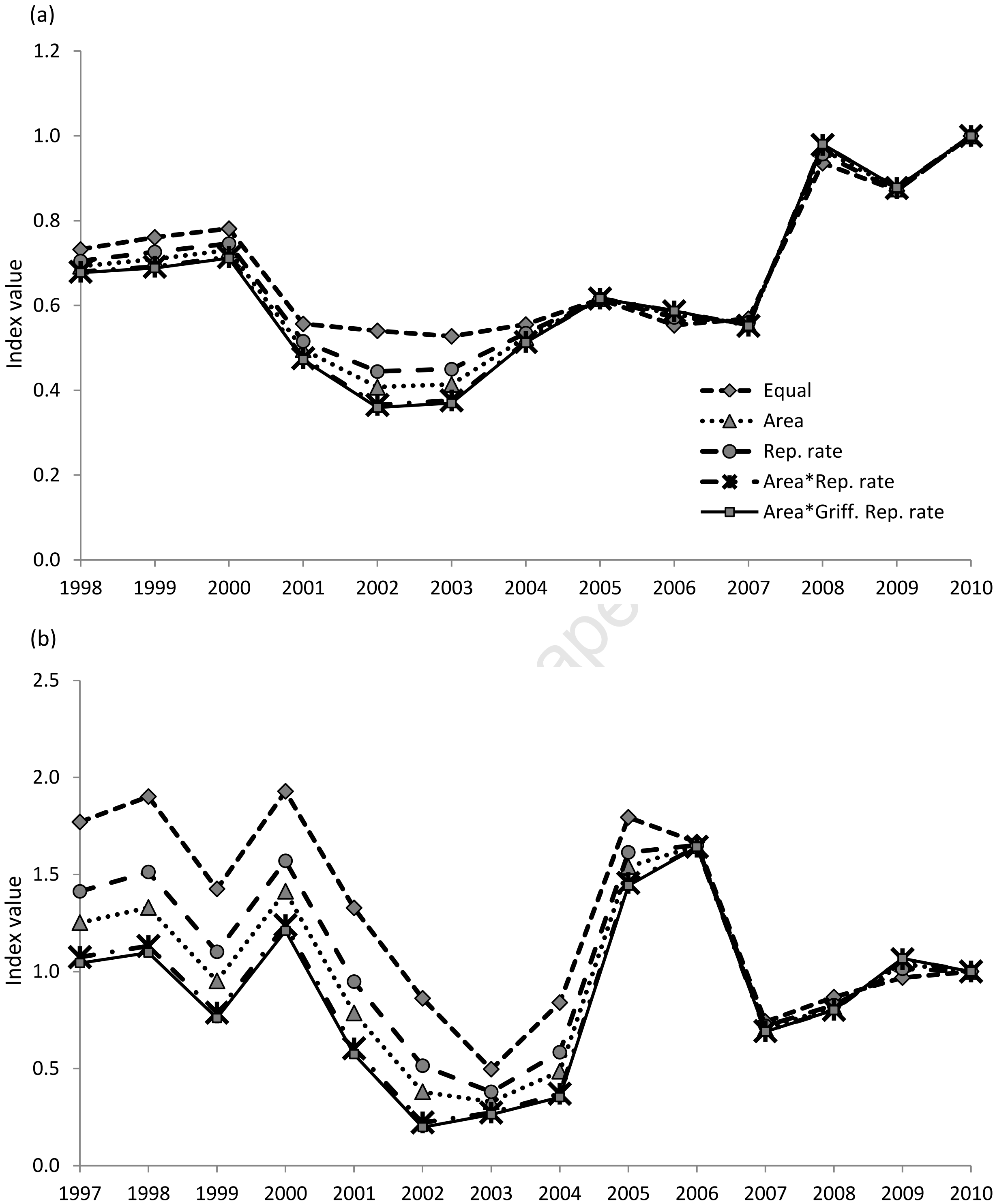

Figure 6: National indices for Southern Black Korhaans for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weights, each one represented by one set of points and a line. “Equal” had equal weights for each precinct. “Area” had precincts weighted by their relative area, and “Rep. rate” had precincts weighted by SABAP1 reporting rates for Southern Black Korhaans for that precinct. “Area*Rep. rate” weights used area and reporting rate multiplied together, and “Area*Griff. Rep. rate” used area multiplied by the logarithmic conversion of reporting rates suggested by Griffioen (2001).

Appendix 1. Supplementary data for Chapter 3

Table A1.1: Results of population trend analysis of CAR project data for Southern Black Korhaans, for the three precincts in which the number of birds recorded attained the criteria for inclusion (see text): Eastern Cape Karoo, Overberg and Swartland. "Birds/100 km" columns give the count totals estimated using the Underhill index, converted to birds/100 km of road surveyed; "incr" columns show the percent change in population per year, calculated as the slope of the weighted linear regressions; "Δ incr" columns show the change in increment from one year to the next (see text). At inflection points the Δ incr values change from negative to positive or vice versa. R^2 values give the proportion of the variance of the totals explained by the trend line; SD is the standard deviation of the totals, CV is the coefficient of variation, and "% imp" values indicate the percentage of the overall total that was imputed using the Underhill index. Distance gives the distance in kilometres of the routes included in each analysis. For uniformity, all results are presented to two decimal places.

Eastern Cape Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				2.65	–29.00	
1999	4.23	–15.30		1.71	–30.30	–0.01
2000	4.42	–12.60	0.03	3.28	–27.40	0.03
2001	2.82	–8.10	0.05	1.07	–18.10	0.09
2002	1.98	–2.20	0.06	0.00	–0.80	0.17
2003	1.98	4.20	0.06	0.62	21.30	0.22
2004	3.17	9.30	0.05	0.73	37.50	0.16
2005	3.97	12.20	0.03	4.63	38.40	0.01
2006	3.83	13.50	0.01	5.73	27.90	–0.11
2007	3.52	14.00	0.00	2.29	16.10	–0.12
2008	6.43	14.10	0.00	2.79	8.40	–0.08
2009	5.73	13.90	0.00	3.89	5.20	–0.03
2010	6.43	13.10	–0.01	3.49	4.60	–0.01
Mean	4.04	4.68		2.53	4.14	
R^2	0.74			0.47		
SD	1.52			1.69		
CV	37.67			66.72		
% imp	14.55			20.77		
Distance (km)	1063.45			1154.95		

Year	Overberg Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1997				2.26	–11.90	
1998	0.61	–1.40		2.84	–15.90	–0.04
1999	0.82	–2.70	–0.01	2.13	–19.50	–0.04
2000	0.63	–3.70	–0.01	2.13	–21.70	–0.02
2001	0.70	–5.00	–0.01	1.58	–21.20	0.00
2002	0.44	–6.90	–0.02	0.58	–17.40	0.04
2003	0.94	–9.60	–0.03	0.58	–11.40	0.06
2004	0.55	–12.00	–0.02	0.51	–7.00	0.04
2005	0.33	–12.90	–0.01	1.32	–7.30	0.00
2006	0.33	–11.80	0.01	0.93	–11.10	–0.04
2007	0.33	–9.00	0.03	0.74	–14.70	–0.04
2008	0.28	–4.80	0.04	0.23	–15.30	–0.01
2009	0.17	0.80	0.06	0.28	–12.00	0.03
2010	0.55	8.10	0.07	0.63	–5.10	0.07
Mean	0.52	–5.45		1.19	–13.68	
R^2	0.61			0.74		
SD	0.23			0.85		
CV	43.96			70.93		
% imp	5.84			16.31		
Distance (km)	1805.97			1757.19		

Year	Swartland Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1998				2.91	–1.30	
1999	0.67	7.30		2.47	–3.70	–0.02
2000	0.82	1.10	–0.06	3.11	–6.90	–0.03
2001	0.67	–7.70	–0.09	3.22	–10.40	–0.04
2002	1.64	–17.40	–0.10	3.23	–13.90	–0.03
2003	1.04	–25.10	–0.08	0.99	–17.40	–0.04
2004	0.45	–27.20	–0.02	2.47	–21.30	–0.04
2005	0.32	–21.60	0.06	1.98	–25.00	–0.04
2006	0.00	–8.20	0.13	0.71	–27.30	–0.02
2007	0.43	9.50	0.18	0.24	–27.40	0.00
2008	0.32	25.20	0.16	0.82	–25.90	0.02
2009	0.65	34.00	0.09	0.10	–23.40	0.03
2010	0.53	35.50	0.01	0.31	–20.30	0.03
Mean	0.63	0.45		1.74	–17.25	
R^2	0.41			0.79		
SD	0.42			1.23		
CV	66.12			71.03		
% imp	6.75			11.54		
Distance (km)	938.17			980.43		

Table A1.2: Habitat selection by Southern Black Korhaans (SBKs) using Coordinated Avifaunal Roadcounts (CAR) data for the Eastern Cape Karoo, Little Karoo, Overberg and Swartland precincts (Figure 1 in Chapter 1). “Land area” sections give the percentage of each type of land cover (natural or transformed) within a 2 000 m wide buffer zone around each route, as calculated from the National Land-Cover maps for 2000 and 2009 (NLC2000 and NLC2009 respectively; CSIR and ARC 2005, SANBI 2009). “No. SBKs” columns give numbers of birds seen in each habitat type on these routes over the whole count period (1993–2010). “Jacobs index” columns give the values calculated for this index; *r* is the proportion of birds seen in natural habitat to the total number of birds seen on that route, *p* is the proportion of the area of natural habitat to the total land area, and *D* is the index, calculated using the formula presented in Jacobs (1974). Positive values for *D* indicate selection for natural habitat, and negative the reverse. The bottom row contains the overall percentages of each habitat type for each map, the percentage of birds seen in each habitat type, the total number of birds seen altogether (underlined), and the Jacobs index for the whole precinct (excluding routes on which the species has never been seen).

Eastern Cape Karoo summer

	NLC2000 % land area		**NLC2009 % land area**		**No. SBKs**			**Jacobs index**		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EG01	99.85	0.15	98.44	1.56	10	0	**10**	1.00	0.99	**1.00**
EG02	99.36	0.64	98.90	1.10	8	0	**8**	1.00	0.99	**1.00**
EG03	99.21	0.79	98.82	1.18	53	0	**53**	1.00	0.99	**1.00**
EP01	84.90	15.10	97.93	2.07	47	0	**47**	1.00	0.91	**1.00**
EP02	98.39	1.61	98.56	1.44	38	0	**38**	1.00	0.98	**1.00**
EP03	90.30	9.70	96.94	3.06	8	0	**8**	1.00	0.94	**1.00**
EP04	90.40	9.60	97.92	2.08	35	2	**37**	0.95	0.94	**0.04**
EP05	99.34	0.66	98.85	1.15	1	0	**1**	1.00	0.99	**1.00**
EP06	70.40	29.60	82.60	17.40	8	7	**15**	0.53	0.77	**–0.48**
EP08	99.10	0.90	98.62	1.38	18	0	**18**	1.00	0.99	**1.00**
EP09	61.70	38.30	72.46	27.54	1	0	**1**	1.00	0.67	**1.00**
EP11	66.45	33.55	63.66	36.34	3	3	**6**	0.50	0.65	**–0.30**
ES01	99.08	0.92	98.56	1.44	4	0	**4**	1.00	0.99	**1.00**
ES02	77.87	22.13	81.70	18.30	1	0	**1**	1.00	0.80	**1.00**
ES03	96.82	3.18	95.30	4.70	24	0	**24**	1.00	0.96	**1.00**
ES05	94.08	5.92	90.37	9.63	16	0	**16**	1.00	0.92	**1.00**
ES07	99.32	0.68	98.78	1.22	2	0	**2**	1.00	0.99	**1.00**
ES08	92.13	7.87	97.68	2.32	21	0	**21**	1.00	0.95	**1.00**
Overall	**91.61**	**8.39**	**93.84**	**6.16**	**96.13**	**3.87**	**310**	**0.96**	**0.93**	**0.32**

Eastern Cape Karoo winter

	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EG01	99.85	0.15	98.44	1.56	22	0	**22**	1.00	0.99	**1.00**
EG02	99.36	0.64	98.90	1.10	32	0	**32**	1.00	0.99	**1.00**
EG03	99.21	0.79	98.82	1.18	82	0	**82**	1.00	0.99	**1.00**
EG04	93.40	6.52	93.12	6.88	7	0	**7**	1.00	0.93	**1.00**
EP01	84.90	15.10	97.93	2.07	41	0	**41**	1.00	0.91	**1.00**
EP02	98.39	1.61	98.56	1.44	86	0	**86**	1.00	0.98	**1.00**
EP03	90.30	9.70	96.94	3.06	24	0	**24**	1.00	0.94	**1.00**
EP04	90.40	9.60	97.92	2.08	44	0	**44**	1.00	0.94	**1.00**
EP05	99.34	0.66	98.85	1.15	3	0	**3**	1.00	0.99	**1.00**
EP06	70.40	29.60	82.60	17.40	26	0	**26**	1.00	0.77	**1.00**
EP08	99.10	0.90	98.62	1.38	13	2	**15**	0.87	0.99	**–0.86**
EP11	66.45	33.55	63.66	36.34	9	2	**11**	0.82	0.65	**0.41**
ES02	77.87	22.13	81.70	18.30	1	0	**1**	1.00	0.80	**1.00**
ES03	96.82	3.18	95.30	4.70	21	4	**25**	0.84	0.96	**–0.65**
ES05	94.08	5.92	90.37	9.63	19	0	**19**	1.00	0.92	**1.00**
ES07	99.32	0.68	98.78	1.22	6	0	**6**	1.00	0.99	**1.00**
ES08	92.13	7.87	97.68	2.32	31	0	**31**	1.00	0.95	**1.00**
Overall	**92.06**	**7.94**	**94.08**	**5.92**	**98.32**	**1.68**	**475**	**0.98**	**0.93**	**0.63**

Little Karoo summer

	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
WC01	49.55	50.45	51.72	48.28	31	0	**31**	1.00	0.51	**1.00**
WK03	69.83	30.17	61.49	38.51	3	0	**3**	1.00	0.66	**1.00**
WK04	76.89	23.11	68.04	31.96	5	0	**5**	1.00	0.72	**1.00**
WU01	96.96	3.04	92.42	7.58	2	0	**2**	1.00	0.95	**1.00**
WU02	95.08	4.92	78.95	21.05	1	0	**1**	1.00	0.87	**1.00**
WU03	85.60	14.40	86.49	13.51	4	0	**4**	1.00	0.86	**1.00**
WU05	51.52	48.48	35.30	64.70	0	1	**1**	0.00	0.43	**–1.00**
WU07	89.82	10.18	81.69	18.31	12	7	**19**	0.63	0.86	**–0.56**
Overall	**77.37**	**22.63**	**69.25**	**30.75**	**87.88**	**12.12**	**66**	**0.88**	**0.73**	**0.45**

Little Karoo winter

	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
WC01	49.55	50.45	51.72	48.28	4	0	**4**	1.00	0.51	**1.00**
WK01	68.38	31.62	60.95	39.05	1	4	**5**	0.20	0.65	**–0.76**
WK04	76.89	23.11	68.04	31.96	10	1	**11**	0.91	0.72	**0.58**
WU01	96.96	3.04	92.42	7.58	4	5	**9**	0.44	0.95	**–0.91**
WU02	95.08	4.92	78.95	21.05	2	0	**2**	1.00	0.87	**1.00**
WU03	85.60	14.40	86.49	13.51	2	0	**2**	1.00	0.86	**1.00**
WU06	67.92	32.08	61.59	38.41	0	1	**1**	0.00	0.65	**–1.00**
Overall	**80.00**	**20.00**	**73.97**	**26.03**	**67.65**	**32.35**	**34**	**0.68**	**0.77**	**–0.23**

Overberg summer

Route	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
OV01	15.04	84.96	3.32	96.68	0	1	**1**	0.00	0.09	**–1.00**
OV05	20.00	80.00	5.13	94.87	2	2	**4**	0.50	0.13	**0.75**
OV06	21.56	78.44	7.50	92.50	7	13	**20**	0.35	0.15	**0.52**
OV07	15.91	84.09	3.71	96.29	2	0	**2**	1.00	0.10	**1.00**
OV08	12.90	87.10	5.38	94.62	0	15	**15**	0.00	0.09	**–1.00**
OV10	8.38	91.62	1.83	98.17	0	1	**1**	0.00	0.05	**–1.00**
OV11	50.08	49.92	38.87	61.13	1	0	**1**	1.00	0.44	**1.00**
OV13	21.01	78.99	5.26	94.74	5	10	**15**	0.33	0.13	**0.54**
OV14	23.40	76.60	8.26	91.74	3	5	**8**	0.38	0.16	**0.52**
OV15	14.02	85.98	3.75	96.25	0	2	**2**	0.00	0.09	**–1.00**
OV16	11.11	88.89	4.85	95.15	6	14	**20**	0.30	0.08	**0.66**
OV19	16.26	83.74	3.95	96.05	4	6	**10**	0.40	0.10	**0.71**
OV20	12.15	87.85	1.44	98.56	1	12	**13**	0.08	0.07	**0.07**
OV21	16.20	83.80	3.22	96.78	1	0	**1**	1.00	0.10	**1.00**
OV23	28.83	71.17	13.67	86.33	0	1	**1**	0.00	0.21	**–1.00**
OV24	47.99	52.01	36.26	63.74	4	0	**4**	1.00	0.42	**1.00**
OV34	96.34	3.66	91.43	8.57	5	2	**7**	0.71	0.94	**–0.72**
Overall	**24.92**	**75.08**	**13.43**	**86.57**	**32.80**	**67.20**	**125**	**0.33**	**0.19**	**0.35**

Overberg winter

Route	NLC2000 % land area		NLC2009 % land area		No.SBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
OV02	16.83	83.17	4.11	95.89	0	1	**1**	0.00	0.10	**–1.00**
OV05	20.00	80.00	5.13	94.87	3	2	**5**	0.60	0.13	**0.83**
OV06	21.56	78.44	7.50	92.50	11	31	**42**	0.26	0.15	**0.35**
OV07	15.91	84.09	3.71	96.29	2	5	**7**	0.29	0.10	**0.57**
OV08	12.90	87.10	5.38	94.62	0	34	**34**	0.00	0.09	**–1.00**
OV10	8.38	91.62	1.83	98.17	0	5	**5**	0.00	0.05	**–1.00**
OV11	50.08	49.92	38.87	61.13	3	0	**3**	1.00	0.44	**1.00**
OV12	30.61	69.39	23.04	76.96	3	1	**4**	0.75	0.27	**0.78**
OV13	21.01	78.99	5.26	94.74	8	8	**16**	0.50	0.13	**0.74**
OV14	23.40	76.60	8.26	91.74	0	23	**23**	0.00	0.16	**–1.00**
OV15	14.02	85.98	3.75	96.25	0	7	**7**	0.00	0.09	**–1.00**
OV16	11.11	88.89	4.85	95.15	11	20	**31**	0.35	0.08	**0.73**
OV19	16.26	83.74	3.95	96.05	2	3	**5**	0.40	0.10	**0.71**
OV20	12.15	87.85	1.44	98.56	0	4	**4**	0.00	0.07	**–1.00**
OV22	21.32	78.68	9.95	90.05	1	0	**1**	1.00	0.16	**1.00**
OV24	47.99	52.01	36.26	63.74	2	0	**2**	1.00	0.42	**1.00**
OV26	47.09	52.91	29.57	70.43	0	7	**7**	0.00	0.38	**–1.00**
OV33	42.33	57.67	28.09	71.91	2	0	**2**	1.00	0.35	**1.00**
OV34	96.34	3.66	91.43	8.57	14	0	**14**	1.00	0.94	**1.00**
Overall	**26.73**	**73.27**	**15.39**	**84.61**	**29.11**	**70.89**	**213**	**0.29**	**0.21**	**0.21**

Swartland summer

Route	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
SW01	2.57	97.43	15.05	84.95	6	0	**6**	1.00	0.09	**1.00**
SW03	21.52	78.48	30.87	69.13	1	7	**8**	0.13	0.26	**–0.43**
SW04	8.48	91.52	19.90	80.10	1	4	**5**	0.20	0.14	**0.20**
SW05	1.27	98.73	9.91	90.09	2	5	**7**	0.29	0.06	**0.74**
SW09	2.55	97.45	11.15	88.85	1	0	**1**	1.00	0.07	**1.00**
SW10	14.96	85.04	35.51	64.49	10	2	**12**	0.83	0.25	**0.87**
SW11	22.57	77.43	15.37	84.63	20	0	**20**	1.00	0.19	**1.00**
SW12	27.07	72.93	38.93	61.07	52	32	**84**	0.62	0.33	**0.53**
SW13	13.47	86.53	30.38	69.62	11	6	**17**	0.65	0.22	**0.73**
SW16	5.28	94.72	13.99	86.01	1	1	**2**	0.50	0.10	**0.81**
Overall	**12.47**	**87.53**	**22.68**	**77.32**	**64.81**	**35.19**	**162**	**0.65**	**0.18**	**0.79**

Swartland winter

Route	NLC2000 % land area		NLC2009 % land area		No. SBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
SW01	2.57	97.43	15.05	84.95	2	0	**2**	1.00	0.09	**1.00**
SW03	21.52	78.48	30.87	69.13	0	5	**5**	0.00	0.26	**–1.00**
SW04	8.48	91.52	19.90	80.10	1	1	**2**	0.50	0.14	**0.72**
SW05	1.27	98.73	9.91	90.09	9	2	**11**	0.82	0.06	**0.97**
SW10	14.96	85.04	35.51	64.49	2	4	**6**	0.33	0.25	**0.19**
SW11	22.57	77.43	15.37	84.63	2	0	**2**	1.00	0.19	**1.00**
SW12	27.07	72.93	38.93	61.07	9	19	**28**	0.32	0.33	**–0.02**
SW13	13.47	86.53	30.38	69.62	5	2	**7**	0.71	0.22	**0.80**
SW15	25.25	74.70	14.13	85.87	0	1	**1**	0.00	0.20	**–1.00**
SW16	5.28	94.72	13.99	86.01	0	1	**1**	0.00	0.10	**–1.00**
Overall	**14.40**	**85.60**	**23.13**	**76.87**	**46.15**	**53.85**	**65**	**0.46**	**0.19**	**0.58**

Table A1.3: Four sets of unequal weights used to produce the national population indices for the Southern Black Korhaan. (The fifth set used equal weighting, i.e. a weight of 0.33 for each precinct.) The area of a precinct was defined as that of all the quarter-degree grid cells the routes of the precinct entered. This was also the area for which reporting rates (RR, defined as the percentage of atlas lists from a precinct which reported Southern Black Korhaans) were extracted. Reporting rates from SABAP1 were used (Harrison et al. 1997). For the "Area*Griffioen RR" weightings, the conversion proposed by Griffioen (2001) was applied to the reporting rates (see text) before multiplying them by the precinct areas.

	Area		RR		Area*RR		Area*Griffioen RR	
Precinct	**km^2**	**Weights**	**%**	**Weights**	**km^2*%**	**Weights**	**km^2*(–*ln*(1–RR))**	**Weights**
E Cape Karoo	33402.90	0.53	41.34	0.45	1380731.08	0.64	17815.04	0.66
Overberg	17706.28	0.28	29.23	0.32	517555.38	0.24	6121.69	0.23
Swartland	12307.75	0.19	21.71	0.24	267227.50	0.12	3012.66	0.11

Table A1.4: National population index values calculated for the Southern Black Korhaan using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weightings given in Table A1.3 and summing the results for each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1998	0.73	0.69	0.71	0.68	0.68
1999	0.76	0.71	0.73	0.69	0.69
2000	0.78	0.73	0.75	0.71	0.71
2001	0.56	0.50	0.52	0.48	0.47
2002	0.54	0.41	0.44	0.37	0.36
2003	0.53	0.41	0.45	0.38	0.37
2004	0.56	0.52	0.53	0.51	0.51
2005	0.61	0.62	0.62	0.62	0.62
2006	0.55	0.58	0.57	0.59	0.59
2007	0.57	0.56	0.56	0.55	0.55
2008	0.94	0.97	0.96	0.98	0.98
2009	0.87	0.87	0.87	0.88	0.88
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1997	1.77	1.25	1.41	1.07	1.04
1998	1.90	1.33	1.51	1.13	1.10
1999	1.43	0.95	1.10	0.79	0.76
2000	1.93	1.41	1.57	1.24	1.21
2001	1.33	0.79	0.95	0.60	0.57
2002	0.86	0.38	0.51	0.22	0.20
2003	0.50	0.33	0.38	0.27	0.26
2004	0.84	0.49	0.58	0.37	0.35
2005	1.79	1.54	1.61	1.46	1.44
2006	1.67	1.65	1.65	1.64	1.64
2007	0.74	0.71	0.72	0.69	0.69
2008	0.87	0.82	0.83	0.80	0.80
2009	0.97	1.04	1.01	1.06	1.07
2010	1.00	1.00	1.00	1.00	1.00

Chapter 4

A threatened invader? The case of the Blue Crane *Anthropoides paradiseus*

When we hear his call we hear no mere bird. We hear the trumpet in the orchestra of evolution. He is the symbol of our untamable past, of that incredible sweep of millennia which underlies and conditions the daily affairs of birds and men

~ A Leopold, 1949

Swiftly and yet without haste – that is the elegance of cranes – the three paradisea *move away, and soon the pale heads vanish in the grasses*

~ P Matthiessen, 2001

Abstract

The Blue Crane *Anthropoides paradiseus* is South Africa's national bird and classified as Vulnerable because of large population declines in the Grassland biome, the former core of its range. However, it was thought to be increasing in abundance in agricultural areas in the Fynbos biome. This study assessed the status of the population using data from two long-term public participation bird monitoring projects. Population trends produced using Coordinated Avifaunal Roadcounts (CAR) project data for 1993–2010 suggested that Blue Crane abundance increased in the Western Cape and in one precinct in the Free State, but decreased or remained constant in other precincts. Comparison of data from the first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992, and SABAP2, 2007–) showed that Blue Crane reporting rates increased in the Fynbos and grassy Nama Karoo biomes, but decreased in the rest of the species' range. CAR habitat use data showed that cranes selected transformed habitats over natural in most precincts and seasons; this preference was strongest in the Fynbos biome and weakest in the Grassland biome. National population indices produced using CAR and SABAP data showed that the population increased by 200–300% within the area covered by CAR.

Introduction

The Blue Crane *Anthropoides paradiseus* is endemic to southern Africa and near-endemic to South Africa; it is the most range-restricted of the world's 15 crane species (Archibald and Meine 1996) and South Africa's national bird. Along with the Demoiselle Crane *A. virgo*, an inhabitant primarily of the Palearctic, it is the least reliant on wetlands of the cranes, and spends most of its time in dryland habitats, using wetlands only to roost in at night (Archibald and Meine 1996). The Blue Crane's natural habitat is grasslands and the grassy ecotone between the Grassland and Nama Karoo biomes (Figure 1a), where annual summer rainfall exceeds 300 mm (Allan 2005). The species probably did not occur in the Western Cape originally, but possibly as early as the late 1800s it began to colonise parts of the Fynbos biome that had been converted to agriculture (Allan 1997a, 2005). Initially the rate of population increase in this area was slow, but with changes in the dominant farming practices that occurred from the 1960s onwards, Blue Crane numbers began to increase more rapidly. Around the same time, however, their populations in the Grassland biome began to decline (Allan 1994, 2005).

In 1974 the results of a country-wide survey led to the conclusion that "the Blue Crane population is healthy throughout South and South West Africa and is nowhere endangered" (van Ee 1981). However, by the 1980s steep declines in grassland populations of the species were apparent (Allan 1993), and in 1994 the species was listed as Vulnerable on the IUCN Red List (BirdLife International 2012). The main causes of this decline are thought to be human population pressure, poisoning (both intentional and inadvertent), collisions with overhead powerlines, loss of habitat and disturbance by humans and domestic animals (Archibald and Meine 1996, Allan 1997a, 2005). Extensive monitoring and conservation programmes were established, including captive breeding programmes, aerial surveys, a national crane census and a range of other projects. Most of these efforts were focused in the east of the country, where the population was declining, but in the late 1980s and early 1990s David Allan conducted an extensive set of roadcounts of Blue Cranes and Denham's and Ludwig's Bustards *Neotis denhami* and *N. ludwigii* in the west (Allan 1993). This project confirmed the sharp increase in Blue Crane densities in the Western Cape, and led to the establishment of the Coordinated Avifaunal Roadcounts (CAR) project with the aim of monitoring Blue Crane and Denham's Bustard populations in agricultural regions of this province. The project soon expanded its reach and its aims, and by 1998 covered much of the Blue Crane's range (Chapter 1, Young et al. 2003). The first Southern African Bird Atlas Project (SABAP1) had by 1992 also collected much valuable data on the species (Harrison et al. 1997), and in 2007 SABAP2 began to accumulate a new set of data with which the earlier set could be compared. A distribution map created using both SABAP1 and SABAP2 data available as of 10 February 2012 shows that the distribution of the species was contiguous and reporting rates were high in the Western Cape, that the distribution was more patchy in the Eastern and Northern Cape provinces, and that it was extremely patchy and reporting rates were low in the species' former stronghold in the eastern half of the country (Figure 1b).

This study aims to use the data from the CAR project, SABAP1 and SABAP2 to determine the current status of the Blue Crane, a species which appears to be both increasing and decreasing in abundance, using methods developed in an earlier study (Chapter 3). CAR project data are used to assess population trends of the species in as many areas as possible, and to examine habitat use and selection in these areas to gain a better understanding of the needs of and challenges for this species. SABAP data are compared numerically to further examine the changes in status of the species between the two data collection periods. Finally, CAR data and SABAP data are combined to produce a national population index for the species.

Methods

CAR project

Data collection

The CAR project was initiated in 1993 in the Overberg region of the Western Cape, and expanded throughout the range of the Blue Crane over the following eight years (Chapter 1; Young et al. 2003). Volunteers undertook surveys of defined "routes", with a target distance of about 60 km each. The routes, which were primarily through agricultural areas, were surveyed twice a year, once in summer and once in winter. Blue Cranes observed along the route were counted according to a strict protocol, and relevant variables were collected (Chapter 1). Allan (1993) considered that 1 500 m is the maximum distance at which Blue Cranes are visible from a road when using binoculars; in many places the distance visible from the road is greater than this. We thus interpret the counts as an index of the number of Blue Cranes within a transect 3 000 m wide, symmetrically placed on either side of the route. However, CAR observers did not record the distance from the road of each sighting, precluding the application of "distance sampling" (Buckland et al. 1993) to the data; it was therefore not possible to transform the counts into densities. Thus one of the constraints imposed by the data collection protocol is that the results need to be expressed in linear units; the convenient metric is birds per 100 km.

Analysis – population trends

The CAR routes were separated into "precincts" — ecologically distinct areas with similar vegetation and climate characteristics — based on the precincts used in the Mazda CAR report (Young et al. 2003) and by examining vegetation maps (Mucina and Rutherford 2006) of areas surrounding any new routes. Count data for each precinct were analysed separately. Only precincts with sufficient data for a meaningful analysis were used; the estimated total number of birds for entire precinct and period both counted and imputed (see Chapter 3 for precise definition) was greater than 100. Summer and winter surveys were analysed separately.

The Underhill index (Underhill and Prŷs-Jones 1994) was applied to the data (Chapter 3). The resulting annual precinct totals were analysed in the same way as those for the Southern Black Korhaan *Afrotis afra* (Chapter 3).

Analysis – habitat use

Habitat use data collected by CAR project participants were extracted and summarised. Additional precincts were included which did not have sufficient data for the population trend analysis, but did for the habitat selection analysis. Precincts were included if the number of routes on which Blue Cranes were observed in at least one of the seasons was five or more.

Habitat selection and habitat use were analysed as for the Southern Black Korhaan (Chapter 3), with the following exceptions. Habitat availability was calculated using the 1994 National Land-Cover map (NLC1994) (Thompson 1999) in addition to NLC2000 and NLC2009 (CSIR and ARC 2005, SANBI 2009). The earlier map was included so as to give a more accurate representation of habitat availability for the entire period over which Blue Cranes were surveyed (1993–2010). Buffer zones formed around each route were 3 000 m wide, because Blue Cranes up to 1 500 m from the road could have been recorded by CAR observers (Allan 1993).

SABAP

Data collection

The first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) represent distinct iterations of southern Africa's largest-scale bird monitoring project (Harrison et al. 2008). The protocol used for SABAP1 (1987–1992) is described in Chapter 1 and in Harrison and Underhill (1997), and for SABAP2 (2007–) on the project's website (http://sabap2.adu.org.za/), and a summary is provided in Chapter 1.

SABAP comparison map

We used a visual method, termed a SABAP comparison map, to examine the changes in raw reporting rates for the species from the first atlas project to the second, using all data submitted up until 10 February 2012 (Chapter 3). A statistic which takes into account the difference in reporting rates and sample sizes of checklists was calculated for each atlas quarter-degree grid cell (QDGC) to evaluate the importance of these changes (Chapter 3). The categories of QDGCs in each province were counted and these totals were summarised graphically to aid interpretation of the map.

National population trend index

The status of the Blue Crane population as a whole was modelled using the method developed for the Southern Black Korhaan (Chapter 3). For precincts which were not surveyed in the earlier years of the project, the density for the first year of surveys was applied to the years before that. For precincts where years of data were excluded from the Underhill index, these years were included for this analysis, unless the reason for excluding them was that the only routes which were surveyed in those years had no Blue Cranes on them. This was done because the estimation by the Underhill index was deemed to be of higher quality than simply applying the density estimate for the closest year that was included.

Results

CAR project

Population trends

Fourteen precincts had sufficient data for Blue Cranes to be included in the population trend analysis. The precincts were Eastern Cape Coastal, Eastern Cape Karoo, Eastern Karoo, Little Karoo, North-eastern Eastern Cape, North-eastern Free State, Northern KwaZulu-Natal (summer only), North-western Free State (winter only), Overberg, Southern Free State, Southern KwaZulu-Natal, Swartland, Western KwaZulu-Natal and Wakkerstroom precincts (Figure 1 in Chapter 1). The number of years of data varied between 11 and 18, and the number of routes per precinct varied between seven and 78, with a median of 20 (Table 1). To ensure that the percentage of the overall total imputed in each analysis was less than 25%, the data were adjusted as appropriate (Table 2).

Blue Crane populations increased unequivocally over the study period in three precincts: Little Karoo (CAR totals increased by c. 400%), Overberg (summer: c. 500%; winter: c. 200%) and Southern Free State (c. 300%); in the Swartland populations increased (totals increased by at least 300%) and then began to decrease, and there was a decrease in Western KwaZulu-Natal (Figure 2; Appendix 2, Table A2.1). In two precincts survey totals increased in one season only: Eastern Karoo (summer) and Southern KwaZulu-Natal (winter), and in Southern KwaZulu-Natal the totals decreased in summer. In the North-eastern Eastern Cape and Wakkerstroom precincts a weak increasing trend was apparent, and in the remainder of precincts there was no trend in totals.

Overberg population densities were four to five times larger than the largest values elsewhere. Overall, the average summer density was 126.4 birds/100 km (SD 43.2); this increased from 41.2 birds/100 km in 1994 to 192.9 birds/100 km in 2010. This represented an average annual rate of increase of 8%. For winter counts the average density was 239.5 birds/100 km (SD 66.1), ranging from 129.1 birds/100 km in 1993 to 376.4 birds/100 km in 2005. Overall the average annual rate of increase was 4%. Densities in winter were on average approximately double those of the immediately preceding summer. Although they were more variable in absolute terms, the CV was lower (34.2% for summer and 27.6% for winter). The linear trend line explained most of the variability in summer, but performed less well in winter ($R^2 = 0.95$ for summer and 0.77 for winter).

In most precincts the pattern between summer and winter observations was similar to that for the Overberg: average winter totals were larger than those for summer, usually more than double (Eastern Cape Coastal, Eastern Cape Karoo, Eastern Karoo, Little Karoo, North-eastern Free State, Swartland), and in one case almost quadruple the summer average (Southern Free State). In three of the precincts analysed totals for winter were lower than those for summer: North-eastern Eastern Cape, Southern KwaZulu-Natal and Northern KwaZulu-Natal (the totals for the latter precinct were so low that that data series did not meet the criteria for inclusion in this analysis). The absolute variability of annual totals was higher in winter than in summer in all precincts except Southern KwaZulu-Natal, although the CV was larger in seven precincts: Eastern Cape Coastal, Eastern Cape Karoo, North-eastern Eastern Cape, North-eastern Free State, Southern KwaZulu-Natal, Swartland and Western KwaZulu-Natal. Trend lines explained at least 50% of the variability in the totals ($R^2 \geq 0.50$) in 12 of the 26 analyses (Appendix 2, Table A2.1).

After the Overberg, the precincts with dense populations of Blue Cranes were the Swartland, Little Karoo, Eastern Karoo and Eastern Cape Karoo (summer densities ranging from 13.3 to 24.8 birds/100 km, winter from 53.6 to 67.9 birds/100 km). The next most densely populated precincts were the remaining Eastern Cape precincts and the Free State precincts (4.1–30.0 birds/100 km), and those with the lowest densities were the KwaZulu-Natal and Mpumalanga precincts (0.9–4.4 birds/100 km). Average annual rates of population increase were similar in the Little Karoo (14%), Southern Free State (c. 15%) and in the Swartland until about 2007 (14% for summer, 21% for winter). After 2007 Swartland totals decreased by 2% per year in summer, and after 2008 by 7% per year in winter. Inflection points for these changes in trend direction occurred in 2002–03 for the summer trend and in 2004–05 for winter. Eastern Karoo summer totals increased by an average of 8% per year, and the Southern KwaZulu-Natal winter totals increased by 13% per year, while summer totals for this precinct decreased by 5% per year. Western KwaZulu-Natal totals were variable from year to year and the totals for some years in the middle of the series were at least double the initial totals, but no Blue Cranes were seen in this precinct in either 2009 or 2010, and overall the count totals decreased by c. 19% per year.

Habitat use

The additional precincts that were included in this analysis were Gauteng and Steenkampsberg (Figure 1 in Chapter 1). Blue Cranes preferred transformed land unequivocally in both seasons in nine precincts and in winter in a further five (Table 3; Appendix 2, Table A2.2). In no precincts did they select for natural habitats in both seasons. The strongest preference for transformed habitats was shown in the Western Cape precincts. In the Eastern Karoo, birds showed a strong preference for transformed land according to the Jacobs index for the whole precinct, but in terms of the number of routes on which a preference was shown either way, the birds favoured natural habitats. This apparent contradiction is an artefact; see Discussion.

Preference was shown for natural habitats in summer and transformed land in winter in the Eastern Cape Karoo, Gauteng, Northern KwaZulu-Natal, Southern Free State, Wakkerstroom and Western KwaZulu-Natal precincts (sign test for summer was significant for Eastern Cape Karoo, Northern KwaZulu-Natal and Southern Free State, and for winter was significant for Wakkerstroom and Western KwaZulu-Natal; Table 3).

In terms of the specific agricultural habitats Blue Cranes used, the majority of birds seen in summer surveys were in natural habitats or at water in all but six precincts: Eastern Cape Coastal, Little Karoo, North-eastern Free State, North-western Free State, Overberg and Swartland (Figure 3a). In winter the majority were recorded in natural habitats or at water in three precincts: Eastern Cape Karoo, Eastern Karoo and Southern Free State (Figure 3b). Important habitats (more than 10% of birds were recorded therein) in the three Western Cape precincts in summer were crop stubbles, fallow land, crop fields in the Little Karoo and pasture in the Overberg. In winter they were fallow land, crop fields, pasture in the Overberg and Swartland, and bare land in the Little Karoo.

In summer outside the Western Cape, transformed habitats of importance were pasture, crop stubbles, bare land and crop fields. In winter an average of 37% of the birds were seen in natural habitats or at water. Other important habitats were crop stubbles, pasture, fallow land, crop fields, bare land and other agricultural land, including burnt and mown land and feedlots.

Because crop fields were important in several precincts in both seasons, sightings in this habitat were broken down further into crop types (Figure 4). Cereal crops (including oats, maize and wheat) accounted for the majority of these sightings in most precincts. Where crops could not be distinguished as cereal or non-cereal they were recorded only as "crops", so usage of cereal crops was likely to be higher than indicated by the cereal crops categories alone. Prickly pear plantations were important in the Eastern Karoo in summer, with 81% of crop field sightings in this habitat. Orchards were used only in the Eastern Karoo (19% in summer, 8% in winter) and Swartland (1% in summer) precincts. Only two birds were ever recorded in vineyards, and this was in the Swartland in summer. Canola fields were used by 61% of the birds in the Eastern Cape Karoo in winter and were used by a small number of birds in several other precincts in both summer and winter. Lupins were important only in the Swartland in winter.

SABAP

SABAP comparison map

Over the whole of the Blue Crane's range in South Africa, reporting rates declined in 63% of QDGCs (yellow, orange and red QDGCs, Figures 5 and 6). This decline was important (orange and red QDGCs) in 20% of all QDGCs for which the species was reported in either atlas project. In six provinces more than 75% of QDGCs for which the species was ever reported showed decreased reporting rates: Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga and North West. In the Western Cape 74% of QDGCs showed increased reporting rates (blue, dark green or light green QDGCs).

Areas of increase were contiguous in the Western Cape and in the south-west of the Eastern Cape, and patchy or scattered in the remainder of the range. Some areas where there was a small cluster of QDGCs with increased reporting rates, such as that in the southern Free State, were adjacent to areas of significant decrease. Areas of significant decrease were contiguous in KwaZulu-Natal, the north-eastern Free State and Gauteng, and were scattered or patchy elsewhere. A large proportion of the grid cells in which reporting rates had decreased had SABAP2 reporting rates of zero.

National population index

The five sets of weightings developed for the national population index differed from each other, except that the area*reporting rate and area*Griffioen reporting rate weightings were similar (Appendix 2, Table A2.3). Some precincts were affected more than others by the different weightings, for example the Southern Free State received a weighting of 0.24 (summer) or 0.22 (winter) in the area weightings, but 0.05 in the reporting rate weightings. This precinct's weighting in the area*reporting rate and area*Griffioen reporting rate weightings was 0.12–0.14. Overberg received a weight of 0.06 for area, 0.13–0.14 for reporting rate and 0.10–0.12 for the weightings including both area and reporting rate. Northern KwaZulu-Natal received weightings of 0.06, 0.11 and 0.08 for the same sets of weightings.

National population indices were largely similar (Figure 7; Appendix 2, Table A2.4). Summer indices indicated that the population had increased from 27–32% of its current level, with spikes in 2003 for all indices, 2005–06 for only the equal weighting index, and 2009 for the equal weighting and area-only weighted indices. Winter indices were not as similar to each other as the summer indices were, but nonetheless were close, and all indicated that the population had increased from 39–47% of its current level. There were spikes in 2004 for all indices with weightings involving area, or 2005 according to the other two indices, and in 2008. Minima and maxima in the series were most pronounced in the indices weighted by both area and reporting rate.

Discussion

CAR project

Population trends

This study confirms current wisdom on the status of the Blue Crane: the core of the range by the late twentieth/early twenty-first century was in the Western Cape, a region that the species did not inhabit prior to anthropogenic land transformation (Allan 1997a) and probably first colonised in the late nineteenth century (Allan 2005). The population in the original core of its range (the Grassland biome) had decreased to such an extent that densities there were a small fraction of those in the Western Cape, and a project such as CAR was no longer capable of reliably detecting trends in these populations in many areas. The population in much of the Western Cape increased during the study period (Figure 2). The rate of increase in the most densely populated region, the Overberg, although initially approximately 20% per year for summer totals and 9% for winter, stabilised within the first few years of surveys to c. 5% for summer and c. 3.5% for winter and remained consistent for the remainder of the study period. The Swartland population, however, may have reached or exceeded its carrying capacity, or the environment began to change to the detriment of the species, in the mid-2000s, because its rate of increase began to decline between 2002 and 2005, and the population itself began to decline slowly in 2007 or 2008. Observations made in 2010 and 2011 suggested that the species was expanding its range into the Succulent Karoo biome, and further into the Nama Karoo biome than it had been recorded previously (SABAP2 unpubl. data, Simmons 2011). It seems likely that these areas became accessible to Blue Cranes because of the presence of man-made water reservoirs and the species' relatively recent establishment in the Swartland, which put the newly colonised areas within easy reach (the furthest these birds have been observed to move is c. 120 km) (McCann et al. 2001, Allan 2005).

The present results for the initial years of Overberg surveys agreed well with the results from a previous study: Allan (1997b) found average densities of 37.7 birds/100 km for summer and 123.0 birds/100 km for winter, for surveys conducted using a similar protocol from 1988 to 1993. These figures are close to the present results of 41.16 birds/100 km for summer in 1994 and 129.05 birds/100 km for winter in 1993, and provide confirmation of the reliability of these results.

The dramatic population increase in the Western Cape is likely to have occurred primarily through a substantially larger than normal rate of breeding success, because of the increased availability of suitable breeding habitat and food. Young birds may also be recruited into the breeding population at an earlier age than they would if the population were at carrying capacity, because of a surplus of suitable breeding territories. A dearth of natural predators may also be a factor; some of this species' natural predators may be grassland specialists which are not present in the Fynbos biome.

The populations in the former core of the range experienced their greatest declines before the CAR project was established in that area (Allan 2005). The principal mechanisms of this decline were probably greatly increased mortality, largely due to poisoning but also caused by powerline collisions, hunting and other forms of persecution, and greatly decreased breeding success, due to habitat destruction and disturbance. Although poisoning incidents became less common over the course of the study period, habitat destruction was not reversed. During the study period, therefore, there may not have been sufficient suitable habitat available to allow the population to expand once more, added to which human disturbance and powerline collisions probably still contribute to an above-normal mortality rate and below-normal breeding success.

The R^2 measure provides an indication of the proportion of the variability in the totals that is accounted for by the trend line, similar to that used for assessing the fit of linear regressions. However, if the population was more or less stable or the rate of change was low, and the trend line was therefore close to horizontal, it would be close to the mean of the totals, and the proportion of the variability accounted for by this line would necessarily be low (since variability measures the degree of departure from the mean). This measure may therefore be misleadingly low where a population was stable or the rate of change was low, for example in the case of the Eastern Cape Coastal and Southern KwaZulu-Natal summer trends.

The discrepancy between summer and winter count totals, and the higher variability in winter totals, is largely explained by the species' winter flocking behaviour. In summer breeding birds separate into pairs and spread out to occupy breeding territories. They would thus be both more consistent in numbers along CAR routes, and more difficult to detect, than the large flocks that form in winter. The terrain and the density of roads in agricultural areas meant that not all parts of a precinct could be covered by a CAR survey, so there were potentially many breeding territories and thus birds that were not visible from CAR routes. However, large winter flocks tended to gather at feedlots (in the Western Cape province especially), and since these were often close to the road for reasons of accessibility, it is likely that a greater proportion of the population was recorded in winter than in summer, although totals were more variable in some precincts, because of the lower likelihood of observing flocks than dispersed breeding pairs.

Outliers in the data series probably represent isolated sightings of large nomadic flocks. The Southern KwaZulu-Natal trends, for example, each had one point approximately triple the average of the other points, both observed in 2006, in the summer and winter surveys. In summer of that year, three flocks totalling 139 birds were observed within 1.5 km of the beginning of route KG08, and in winter 2006 one flock totalling 112 birds was observed at the beginning of route KG07, c. 10 km away from where the summer flocks were recorded (CAR project, unpubl. data). It is probable that the summer and winter flocks were made up of largely the same group of non-breeding birds, which happened to be resident within this small area in 2006, but which in other years were not covered by the CAR surveys.

There has been much conjecture about partial seasonal migration in Blue Cranes (Allan 1997b), but this cannot be the explanation for most of the increase in count totals in winter since this increase occurred in almost all precincts. The precincts in which the mean population density decreased in winter were the North-eastern Eastern Cape, Northern KwaZulu-Natal and Southern KwaZulu-Natal. This may imply that some of the population left these areas in winter and supplemented the winter populations elsewhere. Allan (1997b) suggested that Blue Cranes move from the Eastern Cape grasslands into the karoo in winter, which may explain the decrease in densities in the North-eastern Eastern Cape in winter and some of the dramatic winter increase in the three karoo precincts. McCann et al. (2001) used satellite telemetry to show that birds in Mpumalanga and KwaZulu-Natal tend to migrate to lower altitudes in winter (south for the Mpumalanga birds and north for the KwaZulu-Natal birds), which may explain the winter decrease in densities in the Southern and Northern KwaZulu-Natal populations. The winter trend for Southern KwaZulu-Natal, however, suggests that while the population as a whole may have decreased (summer trend), the proportion of the population migrating out of the area in winter may also have decreased, or may have varied depending on climatic conditions, leading to the apparent increase in winter population. Winter migration to Wakkerstroom may have increased from 2005 onwards, or the extent of migration away from this precinct may have decreased.

There is one other contemporary data set on Blue Crane populations, in KwaZulu-Natal only (Smith et al. 2010). Unfortunately it is not directly comparable to the CAR data, but a brief examination of those data is nonetheless informative. The Endangered Wildlife Trust (EWT) conducted aerial counts of all crane species over much of their KwaZulu-Natal range annually in July from 2001 to 2010. Their trend for Blue Cranes is relatively stable for the first six years of the series and then begins to increase, although the 2010 total is lower than the previous three years' totals. The areas they surveyed covered much of the same area as the CAR project; their Northern KwaZulu-Natal region corresponded to most of the Western KwaZulu-Natal precinct and approximately half of the Northern KwaZulu-Natal precinct, and the four regions to the south of this together covered most of the Southern KwaZulu-Natal precinct.

The 2010 total for the southern regions was 243 birds, and for the northern region it was 192 birds; most of these birds were seen in large flocks. For the Southern KwaZulu-Natal winter 2010 CAR survey the total of observed and imputed birds was 81, and in the Northern and Western KwaZulu-Natal precincts no Blue Cranes were recorded in winter in either 2009 or 2010. Thus the CAR project in KwaZulu-Natal was missing large numbers of birds, at least in some years. Although the aim of the project was not to count all birds in an area, but to provide an index of the population, it is of concern that no birds at all were recorded in the Western and Northern KwaZulu-Natal precincts, despite these precincts covering a significantly larger area than the aerial survey's northern region. Since the majority of the EWT birds were seen in large flocks in a few relatively small areas, the likelihood of these birds being detected in the winter CAR counts would have depended on whether the CAR routes covered the areas frequented by the large flocks and whether the flocks happened to be within sight of these routes on the day of the count. Much of the topography in KwaZulu-Natal is undulating, so the risk of birds being out of sight would have been higher there than in flat topography.

This leads to the conclusion that the organisers of the CAR project in KwaZulu-Natal should consult with the EWT on the exact locations of these large flocks of Blue Cranes (taking the data from all 10 years of surveys into account), and if possible add new routes so as to maximise the chances of recording these birds. Alternatively, CAR surveys as analysed here may not be able to reliably index Blue Cranes in this province, especially in the Western and Northern KwaZulu-Natal precincts. It is recommended that alternative data analysis methods be sought for rarer species.

Habitat use

The extent of Blue Cranes' use of, and preference for, transformed habitats in the Western Cape shown in this study (Table 3) agreed well with previous findings (Allan 1995, 2005); however, the types of transformed habitats used in different seasons differed to some extent from those reported by Allan (1995). While harvested crop fields ("stubble") were still the most popular habitats in summer in the Overberg and Swartland, fallow land was also important in the Overberg and in the Little Karoo, and crop fields were of roughly equal importance to both fallow and stubble in the latter precinct (Figure 3a). Fallow land is not mentioned by Allan (1995), and according to Young et al. (2003), fallow land comprised only 3.4% of cultivated land in this region in 1999, since the predominant farming system at that time involved rotating crops with cultivated pastures rather than fallow. However, what was recorded as fallow land in the CAR database was probably in fact ploughed or harvested land left bare until the next planting later in the same year (C van Rooyen and W Leeuwner, pers. comms). In winter, while pastures were still the most used habitats in the Overberg, fallow land and crop fields were also important (Figure 3b). Habitat use was different in the other

Western Cape precincts: in the Swartland crop fields were the most popular habitats, followed by pastures and fallow land, and in the Little Karoo fallow land was the most favoured habitat, followed by crops, and natural veld and ploughed land were used by roughly equal numbers of birds. Allan (1995) reported that Blue Cranes only use crop fields in June, when the crop plants are small, and thereafter selected against them, but this did not appear to be the case in the present study, especially in the Swartland and Little Karoo (although the present results were not directly comparable with Allan's, since it was not possible to analyse selection for or against these habitats in this study). However, crops in these precincts tend to be shorter than wheat, which is the predominant crop in the Overberg, so this habitat is therefore more suitable for cranes (DJ Young, pers. comm.).

A study on breeding habitat selection by Blue Cranes in part of the Overberg region found that birds prefer to nest in pasture than in cereal fields, and that they select sites for distance from buildings and tarred roads and proximity to natural vegetation (Bidwell 2004). Nest survival rates were higher in pastures than in crop fields, and c. one fifth of nest failures occurred because of human disturbance during harvesting. The fact that many more birds were observed in stubble fields than in pastures in the summer CAR counts was likely to be because the counts took place in late January, by which stage most eggs have hatched and chicks are mobile (Allan 2005), so adults are no longer restricted to their nesting sites. Even when nests were still active, though, birds were observed to take turns to incubate and the off-duty bird may have foraged elsewhere (pers. obs.), so even nesting birds may not necessarily have been sighted in the habitat in which they were breeding, since they may have selected nesting sites and foraging areas based on different criteria. A noteworthy result from this study was the importance of the proximity of natural vegetation in Blue Crane nest site selection; although it is tempting to think that natural fynbos vegetation is irrelevant to these birds based on the CAR habitat use data, Bidwell (2004) observed a high percentage of adults with chicks moving into natural vegetation when approached by a human, and concluded that this habitat is an important source of cover for chicks before they can fly.

The apparent contradiction between Jacobs index values for the Eastern Karoo precinct as a whole and for individual routes (Table 3) is an artefact of the small proportion of transformed land available in this precinct. Although birds on a highly significant majority of routes appeared to show a preference for natural habitats, this was an artefact of the fact that the transformed habitat was so rare (Appendix 2, Table

A2.2). When the precinct was considered as a whole, although a relatively small number of birds overall was observed in transformed habitats, this proportion was sufficiently larger than the proportion of transformed land available to indicate preference for transformed habitats in this precinct.

It may seem surprising that Blue Crane habitat use in the Little Karoo was more similar to that in the Fynbos biome precincts than to preferences in the other karoo precincts, where natural habitats were still by far the most popular habitats (albeit less so in winter). This was probably related to differences in natural habitats caused by differences in quantity and seasonality of rainfall: in the Eastern Cape Karoo and Eastern Karoo precincts, Blue Cranes inhabit areas of grassy Nama Karoo that receive 200–600 mm of rainfall per annum, mostly in summer (Allan 2005), whereas the Little Karoo precinct comprised a mixture of Fynbos and Succulent Karoo biomes and received rainfall all year round, which totalled between 100 mm and 400 mm per annum (Mucina and Rutherford 2006, Schulze and Lynch 2007, Schulze and Maharaj 2007). Natural habitat in the Little Karoo is therefore probably not optimal for Blue Cranes, comprising as it does mainly shrubby vegetation types in which grass is a minor component.

For the remainder of the species' range, Allan (2005) reported that Blue Cranes occur in grassland, but that at Steenkampsberg in Mpumalanga 38% of birds were in cultivated pastures and crop fields, and that they were tolerant of heavily grazed and burnt grasslands (the remaining 62% were in natural habitats). Results of the present study contradicted this: Blue Cranes favoured transformed habitats in the majority of precincts in winter; the only precincts in which any preference was shown for natural habitats in this season were the Eastern Karoo and Gauteng, and only in terms of numbers of routes, not overall numbers. Natural habitats were unequivocally preferred in summer in only six of the 13 precincts outside of the Western Cape, and in terms of route numbers but not overall numbers in one further precinct. Of the precincts where extensive use was made of transformed habitats even in summer (Eastern Cape Coastal, North-eastern and North-western Free State and Southern KwaZulu-Natal), the latter three were well within the species' original range and the Grassland biome. (The Eastern Cape Coastal precinct, which straddled the Fynbos and Albany Thicket biomes, may only have been colonised as part of the species' range expansion of the nineteenth and twentieth centuries.) This suggests that even where the species' natural habitat was still available to some extent, Blue Cranes were adapting to transformed habitats and making extensive use of them.

Of the transformed habitats used outside the Western Cape, crop stubbles, crop fields and pastures were most popular. These habitats are the most similar of agricultural habitats to natural grassland, but may constitute superior habitat for cranes if they provide more abundant food than natural grassland. It is plausible that they provide increased food in the form of scattered grain and other crop residues, feed provided for livestock, and increased abundance of invertebrates associated with livestock and crops. It was not unexpected that cereals should feature so prominently among the crop types frequented by Blue Cranes, but the extent of their occurrence in prickly pear plantations in the Eastern Karoo was surprising, as was their use of canola fields in the Eastern Cape Karoo and lupins in the Swartland in winter (Figure 4). Although vineyards were relatively common in the Swartland, and were also present in the Overberg, Blue Cranes were never recorded in this habitat. Thus if farming practices in the Western Cape were to shift away from pastures and cereal crops towards a greater predominance of vineyards, as was already occurring in the Swartland during the study period, the area of available habitat for Blue Cranes would decrease. This may explain the decrease in the species' density in the Swartland from 2007–08 onwards.

It is likely that the Blue Cranes' use of natural habitats in summer was related to their habitat requirements for breeding, since natural habitats generally provide more cover and lower disturbance levels. Transformed habitats may have provided a more reliable food supply in winter. Although it no doubt helps the species to survive where its natural habitat has been heavily altered, the birds' extensive use of transformed habitats puts them at increased risk of death by poisoning, which is suspected to have been a major cause of their decline in the former core of their range (Allan 2005). Other threats associated with their use of agricultural land include disturbance and destruction of eggs and chicks in the course of regular farming activities (such as harvesting), predation by dogs and drowning of chicks in water troughs.

SABAP

SABAP comparison map

Changes in SABAP reporting rates largely confirmed the results of the CAR data population trend analysis where clear trends were apparent: Southern Free State (increasing), Overberg (increasing), Swartland (increasing; the slight decrease of 2007–10 would not be expected to reflect in this comparison since overall the population was so much denser in the SABAP2 data collection period than it was during the SABAP1 data collection period), Little Karoo (increasing), Western KwaZulu-Natal (decreasing), Southern KwaZulu-Natal (decreasing, as in the summer CAR trend; Figure 6). Where trends were not apparent in the CAR data this was often due to the inherent variability in CAR count totals for species that were less common, especially those that are nomadic and/or form flocks for part of the year, such as the Blue Crane (Chapter 2). However, in areas where SABAP coverage was good (i.e. the number of lists submitted per QDGC was sufficiently large), there is no reason why atlas reporting rates would not be reliable for a species as conspicuous as the Blue Crane. The similarity between SABAP reporting rate trends and CAR data trends for areas with denser populations of cranes provides further support for the reliability of the SABAP reporting rate trends in general.

Atlas reporting rates for SABAP1 for Blue Cranes were lower in winter than they were in summer in the Western Cape, despite the much higher numbers counted in road surveys similar to CAR counts in winter (Allan 1997b). This phenomenon is caused by the lower likelihood of encountering Blue Cranes when they form large flocks in winter; because SABAP data consisted only of presence/absence data, reporting rates for a species may decrease even if there are more birds visible when the large flocks are encountered (Harrison and Underhill 1997). This may explain the decrease in reporting rates in Southern KwaZulu-Natal, which agreed with the summer CAR trend but contradicted the winter trend. If the average number of winter Blue Crane flocks did not increase between the SABAP1 and SABAP2 data collection periods, but the number of birds in the flocks did increase, the reporting rate would not have been affected, while CAR count totals would have been. In summer, most birds are not in flocks, so a decrease in overall numbers would have affected CAR count totals and atlas reporting rates similarly, causing a decrease in both.

Overall, the SABAP comparison map suggested that the Blue Crane population declined dramatically in the former core of the species' range in the Grassland biome, that the reverse was true in the Overberg and Swartland regions, and that in a broad swath around the eastern boundary of the Nama Karoo biome the species' fortunes were mixed, with possibly a slight overall increase in numbers in this region. The number of QDGCs with zero reporting rates for SABAP2 suggests a significant degree of range contraction. Many of these QDGCs however were colour-coded yellow, i.e. the Z statistic was non-significant. This was primarily caused by the low numbers of SABAP2 atlas lists submitted as of the date of extraction of the data, but also by the low SABAP1 reporting rates. As SABAP2 data collection proceeds the certainty associated with these results is expected to increase, and the number of QDGCs where a significant decline in reporting rates is detected will most likely increase.

National population index

The national population index for the Blue Crane indicated that the population increased by 200–330% over the CAR project study period. The rate of increase was remarkably constant, ranging between 3% and 5% per year. Spikes in the indices were in some instances caused by relatively small unusually large numbers of birds recorded in a few precincts (e.g. the summer 2009 spike was largely caused by unusually large numbers in the Little Karoo, Southern Free State and Wakkerstroom precincts), which were probably caused by isolated sightings of nomadic non-breeding flocks. In other instances they were caused by larger than usual numbers in many precincts, in which case those years may have been good breeding years for Blue Cranes.

The different sets of weightings changed the influence of the precincts according to their importance with respect to the Blue Crane population as a whole, according to different measures. With equal weightings the totals from the Southern Free State precinct, which is a large precinct (69 380 km^2, Table A2.3), were disproportionately under-represented in comparison to the other precincts, all of which were smaller in area, while totals from the Eastern Cape Coastal were over-represented and caused the 2005 spike in the equal weight summer index which was not apparent in any of the other indices. Area weightings addressed this issue, but now the Southern Free State was over-weighted due to the large difference in area between this precinct and the others, and the Overberg precinct was under-weighted because of its relatively small area (17 706 km^2) compared to its importance in terms of numbers of birds. The third index weighted precincts according to their relative SABAP1 reporting rates, with the result that the Southern Free State was even more under-represented than in the equal weightings, due to its low reporting rate, and Northern KwaZulu-Natal's weighting was relatively high due to its high reporting rate in SABAP1. The weightings that involved both area and reporting rate attempted to find the middle ground between these two. They differed by no more than 0.02, and by less than 0.01 in 18 out of 26 cases, so applying Griffioen's (2001) conversion made very little difference in this instance.

From 1993 to summer 1995 only one precinct was surveyed, which increased to two in winter 1995 and three in 1996. By winter 1998 10 of the 14 precincts were being surveyed, by summer 1999 11 were running, and the first year in which all 14 precincts were surveyed was 2000. The indices for the years prior to 1998 (winter) or 1999 (summer) are therefore based mostly on densities obtained in CAR surveys done in other years, and are thus less reliable. This is an unavoidable issue when dealing with data from public participation projects such as the CAR project.

For this analysis only SABAP1 reporting rates were used, since SABAP2 coverage as of January 2012 was not yet sufficient to provide reliable reporting rates for the whole of the Blue Crane's range. This is problematic, since reporting rates changed significantly from SABAP1 to SABAP2 in many areas, so SABAP1 reporting rates in these areas were no longer valid for the latter half of the CAR study period. A case in point is the Northern KwaZulu-Natal precinct. The SABAP1 reporting rate for this precinct was 34%; however, the CAR totals for this precinct suggest that Blue Crane abundance in this precinct was less than 1% of that in the Overberg, for which the SABAP1 reporting rate was 36%. As discussed above, CAR surveys appear to have missed a significant proportion of the Northern KwaZulu-Natal population, so the abundance may have been underestimated by CAR surveys in this precinct. However, the SABAP2 reporting rate for this precinct as at 23 January 2012 was only 8%, while the Overberg reporting rate was 55% (SABAP2, unpubl. data). Thus it is not ideal to use one reporting rate, which applies to the SABAP1 data collection period, to calculate weightings for the entire CAR count study period. Therefore, as SABAP2 coverage improves, this analysis should be updated to include SABAP2 reporting rates as weighting factors. It is suggested that both SABAP1 and SABAP2 reporting rates be used for the years between the two atlas projects, with increasing weight being given to the project whose data collection period was closer to the year in question. It is also likely that data from more CAR precincts will become usable as the project continues, and this will improve the quality of the national index significantly.

Approximately 50% of the species' range was covered by the national population index analysis. This is partly because several CAR precincts in which the species occurred had to be excluded from the population trend analysis due to insufficient data. If all of these precincts could have been included, c. 57% of the range would be covered. The most important parts of the range that would still not be covered are in the central and western Eastern Cape and in the Western Cape around the Beaufort West precinct and between the Swartland and Overberg precincts. The remainder of the range that is not covered is largely around the edges of the range, and Figure 6 indicates that reporting rates for SABAP2 for the majority of these QDGCs were zero as at 10 February 2012, and were less than 10% for the majority of them in SABAP1. Thus those areas would probably not contribute much to the national population index, whereas the areas in the karoo and Fynbos biomes would be likely to contribute significantly, and overall would probably indicate that the population increased more than the index already shows.

Conclusions

Although the Blue Crane population increased dramatically during the study period in the Fynbos biome, it declined in its former range, which covered a much larger area than its new stronghold. This emphasises the vulnerability of this near-endemic species; although its population as of 2010 may appear to have been healthy, if land use practices change in the relatively small area in which the population has become successful, the species as a whole may be under serious threat. It is possible that market forces and climate change may in the future cause viticulture to become more profitable than wheat and livestock farming. If this does occur and the predominant land uses in the Fynbos biome change as a result, Blue Crane populations in this region are likely to decline. There was an increase in the extent of vineyards in both the Swartland and Overberg between 1993 and 2010, but throughout this period this habitat was almost completely avoided by Blue Cranes, indicating that it is not a favourable habitat for this species. Considering Blue Cranes' preference for open, grassy habitats, it is not surprising that a habitat characterised by vines on trellises would not be favoured by them. Apart from a lack of open habitat, which may hinder the birds' ability to detect and escape danger, the supply of suitable food may also be substantially lower in vineyards.

Powerline collisions are also an important threat to this species, and it has been found that the population can only sustain the current rate of mortality because its rate of increase is so high (Shaw et al. 2010). Thus if its rate of increase were to decline, this source of mortality would become more important and Blue Crane numbers would decline further.

In addition to the conservation implications of the above findings, this study demonstrates an effective and novel way of combining data from two public participation projects collecting different types of data, to produce a national index of abundance for a species which is well covered by both projects. This has important implications for improved conservation management, and it is strongly recommended that this method be adapted and applied to a wide range of other similar situations.

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Table 1: Summary of population trend analysis data for the Blue Crane from the Coordinated Avifaunal Roadcounts (CAR) project. The column "Number of routes" gives the number of routes surveyed at least six times in either summer or winter. Average route lengths were calculated from these routes. "Number of years" gives the longest series used in the analysis. "Start year" gives the earliest year from which data were used for this analysis. "Total Blue Cranes" gives the total number of birds seen in these precincts on all routes and in both summer and winter, from the first year in which the precinct was surveyed until 2010 inclusive. Figures are only included for analysed precincts, even though small numbers of birds may have been recorded in other precincts.

Precinct	Number of routes	Ave. route length (km)	Start year	Number of years	Total Blue Cranes
Eastern Cape Coastal	7	52.9	1998	13	2 398
Eastern Cape Karoo	20	57.7	1998	13	10 738
Eastern Karoo	22	58.8	1995	14	14 246
Little Karoo	8	47.6	2000	11	4 434
North-eastern Eastern Cape	20	54.8	1998	12	1 718
North-eastern Free State	29	60.7	1998	13	3 461
Northern KwaZulu-Natal	21	54.9	1998	13	168
North-western Free State	21	61.8	1999	12	725
Overberg	33	54.7	1993	18	111 490
Southern Free State	78	65.2	1997	14	14 777
Southern KwaZulu-Natal	20	56.1	1997	14	1 139
Swartland	16	61.3	1996	15	12 106
Wakkerstroom	7	62.2	2000	11	291
Western KwaZulu-Natal	9	60.7	1997	14	331
Total	311	59.4			178 022

Table 2: Adjustments made to Blue Crane data used for the Underhill index analysis. Seasons are abbreviated as S for summer and W for winter.

Precinct	Season	Adjustment	Comments
Eastern Cape Karoo	W	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
Eastern Karoo	S	2009 and 2010 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
	W	2008 to 2010 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
North-eastern Eastern Cape	S	Route EQ02 excluded	This route caused the percentage imputed to be too high
	W	2010 excluded	Too few routes were surveyed this year for the imputed totals to be realistic
	W	Route EE10 excluded	This route caused the percentage imputed to be too high
North-eastern Free State	W	1997 excluded	Too few routes were surveyed this year for the imputed totals to be realistic
Northern KwaZulu-Natal	S	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
		1997 excluded	Too few routes were surveyed this year for the imputed totals to be realistic
Swartland	S	1995 and 1996 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
Wakkerstroom	S & W	Included routes surveyed at least five times	The whole precinct was only surveyed since 2000 and three important routes had only been surveyed five times
	W	Route MW04 excluded	This route caused the percentage imputed to be too high
Western KwaZulu-Natal	W	Routes KD06 and KL02 excluded	These routes caused the percentage imputed to be too high

Table 3: Habitat selection analysis of Blue Crane CAR data for the 16 precincts for which there were sufficient data (see text), summer (S) and winter (W) counts. Jacobs index *D* values indicate selection for natural habitat if positive, and for transformed land if negative. Numbers in the Natural and Transformed columns are the numbers of routes on which a preference was shown for natural and transformed habitats respectively. Sign test *p* values refer to tests of whether the number of routes with positive Jacobs index *D* values was significantly different from that expected if zero selection had been shown.

Precinct	Season	Jacobs index *D*	Natural	Transformed	Sign test *p* value
Eastern Cape Coastal	S	–0.548	4	4	1.000
	W	–0.201	2	4	0.414
Eastern Cape Karoo	S	0.211	19	5	0.004
	W	–0.881	10	15	0.317
Eastern Karoo	S	–0.667	71	9	< 0.001
	W	–0.841	48	23	0.003
Gauteng	S	0.616	3	1	0.317
	W	–0.616	4	2	0.414
Little Karoo	S	–0.927	1	11	0.004
	W	–0.846	2	9	0.035
North-eastern Eastern Cape	S	–0.209	8	9	0.808
	W	–0.591	4	8	0.248
North-eastern Free State	S	–0.654	15	12	0.564
	W	–0.503	10	17	0.178
North-western Free State	S	–0.408	3	2	0.655
	W	–0.456	3	6	0.317
Northern KwaZulu-Natal	S	0.548	10	2	0.021
	W	–0.494	2	4	0.414
Overberg	S	–0.709	4	34	< 0.001
	W	–0.453	7	31	< 0.001
Southern Free State	S	0.454	47	12	< 0.001
	W	–0.725	20	31	0.123
Steenkampsberg	S	–0.293	3	5	0.480
	W	–0.683	1	2	0.564
Southern KwaZulu-Natal	S	–0.135	10	7	0.467
	W	–0.530	4	14	0.018
Swartland	S	–0.617	1	15	< 0.001
	W	–0.787	0	16	< 0.001
Wakkerstroom	S	0.250	5	2	0.257
	W	–0.774	1	7	0.034
Western KwaZulu-Natal	S	0.598	4	3	0.705
	W	–0.728	1	8	0.020

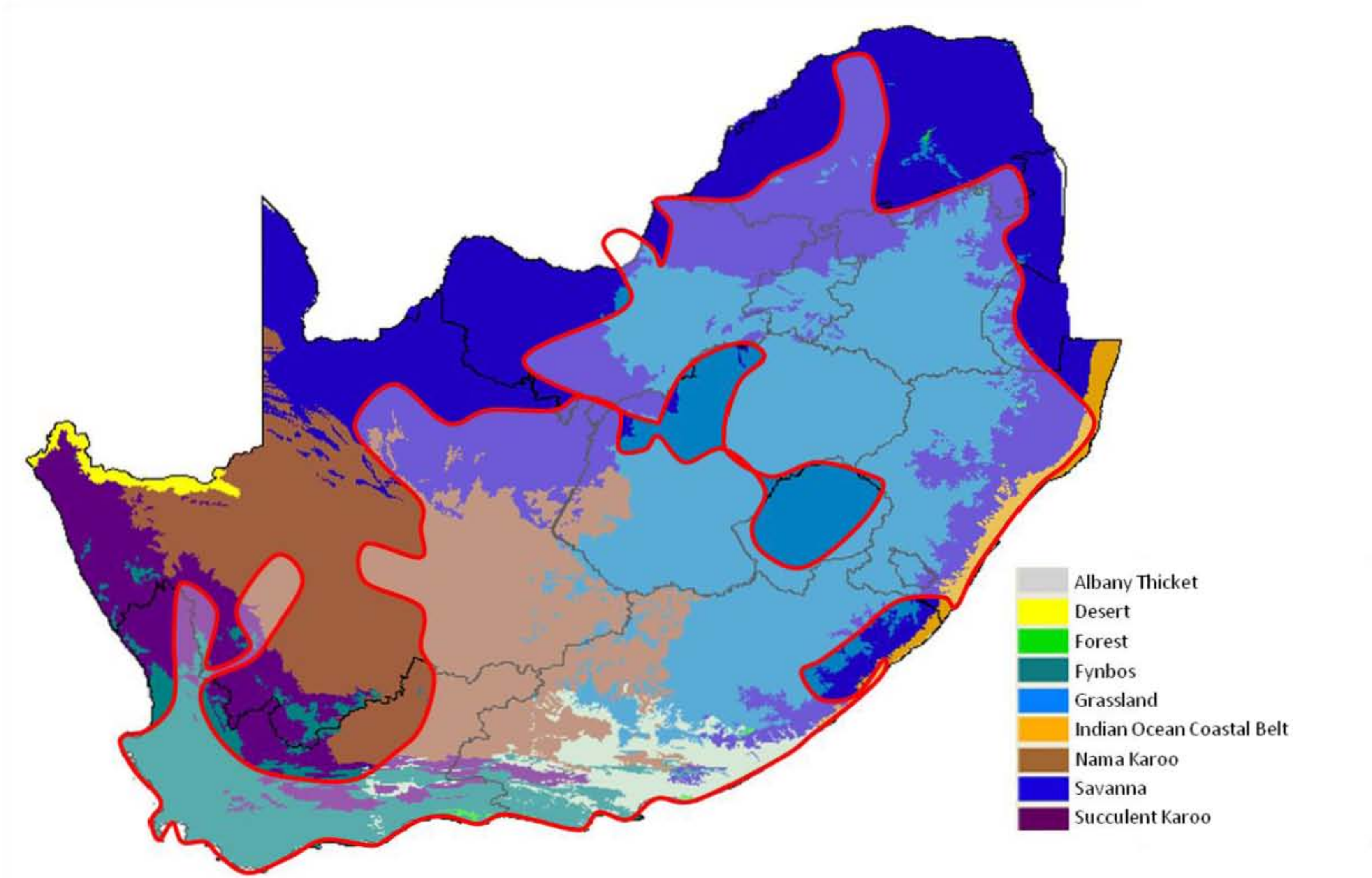


Figure 1a: Biomes (Mucina and Rutherford 2006) and outline of the range of the Blue Crane, drawn using data from SABAP1 (Allan 1997a) and SABAP2 (presented below).

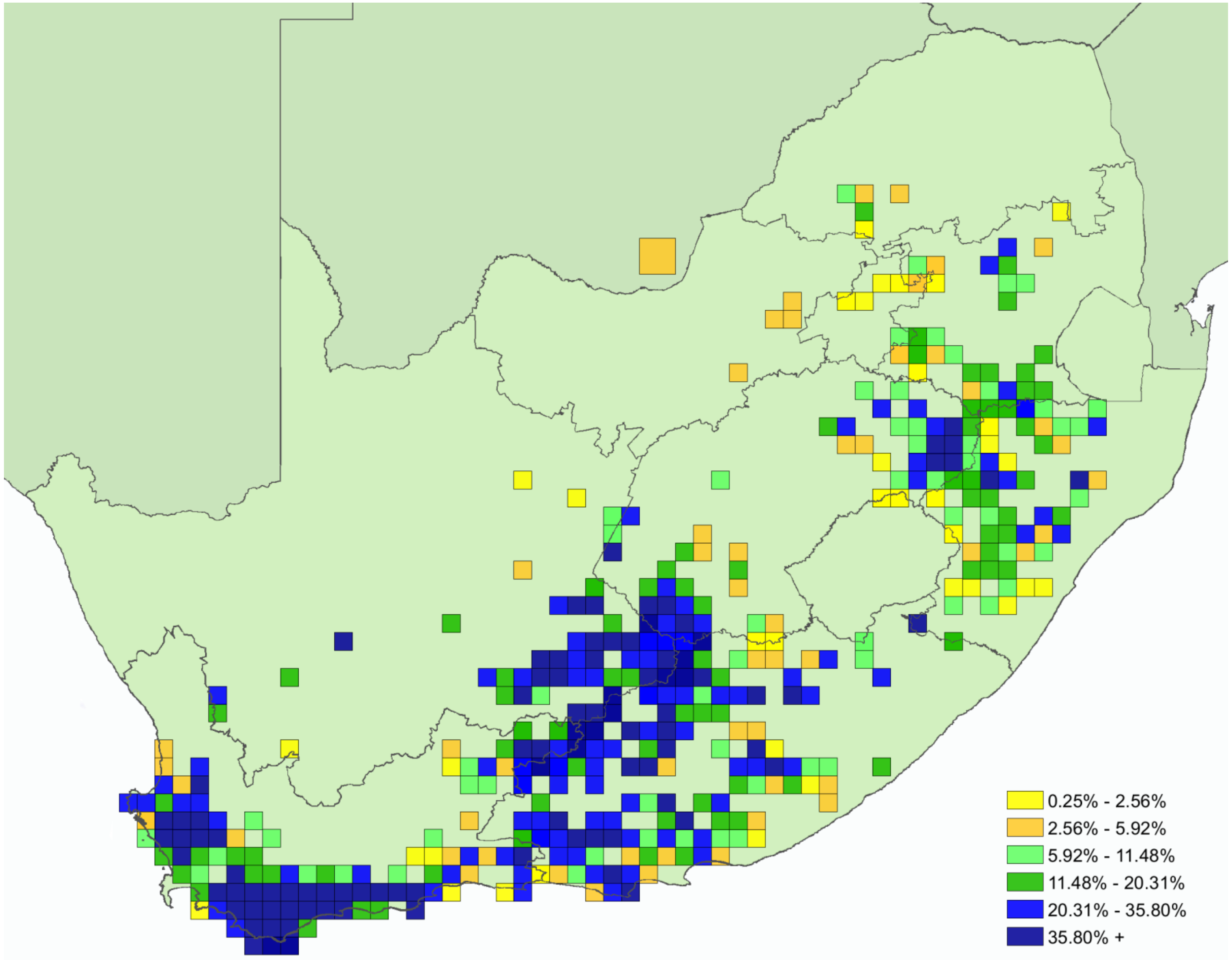


Figure 1b: Range map for the Blue Crane showing derived reporting rates calculated from SABAP1 and SABAP2 data, extracted on 10 February 2012. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15'). Derived reporting rates were calculated as described in Chapter 1.

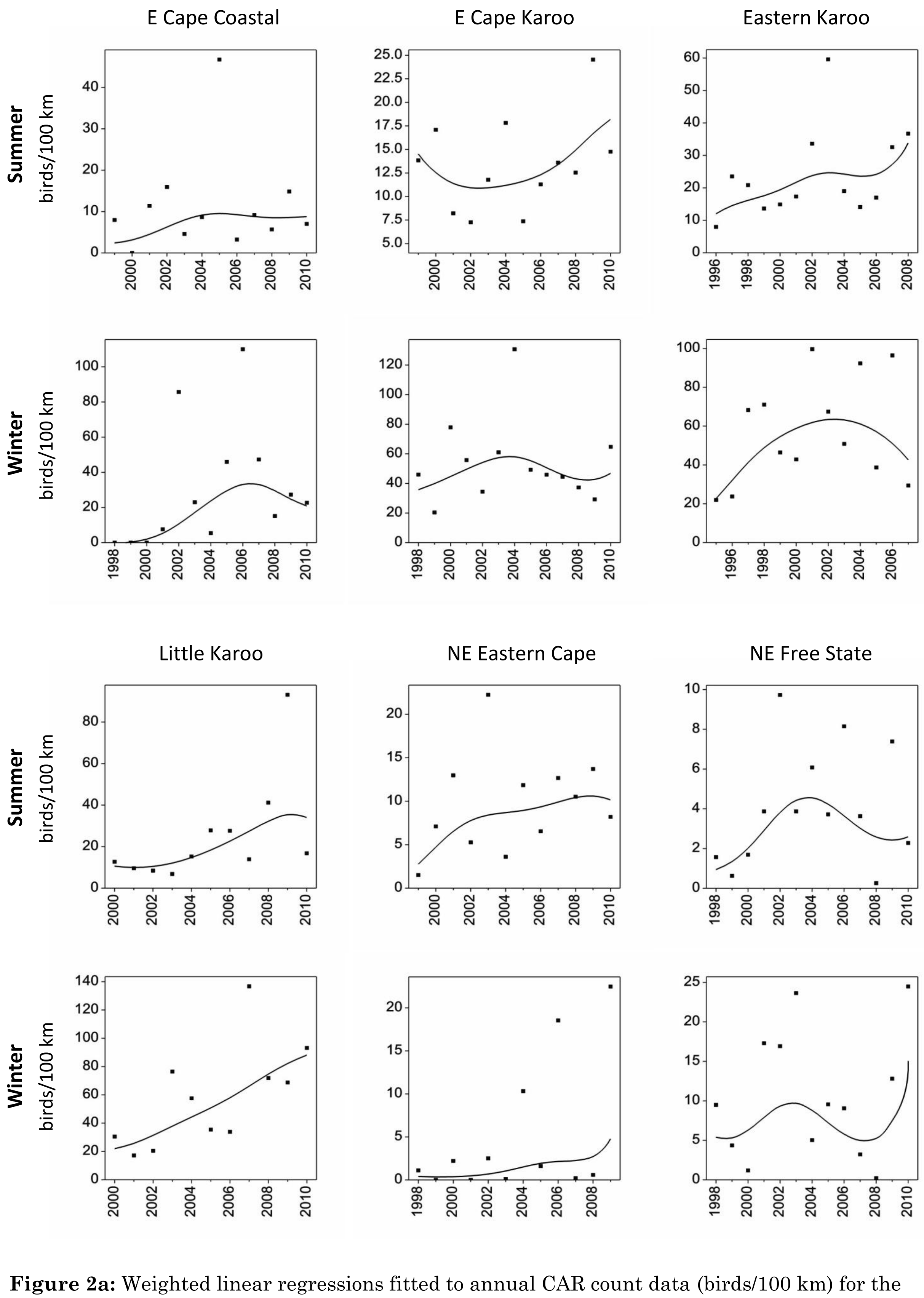


Figure 2a: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Blue Crane for the Eastern Cape Coastal (370 km), Eastern Cape Karoo (summer: 1 063 km; winter: 1 013 km), Eastern Karoo (summer: 1 115 km; winter: 1 126 km), Little Karoo (381 km), North-eastern Eastern Cape (summer: 981 km; winter: 1 035 km) and North-eastern Free State (1 790 km) precincts (Figure 1 in Chapter 1) for summer and winter counts.

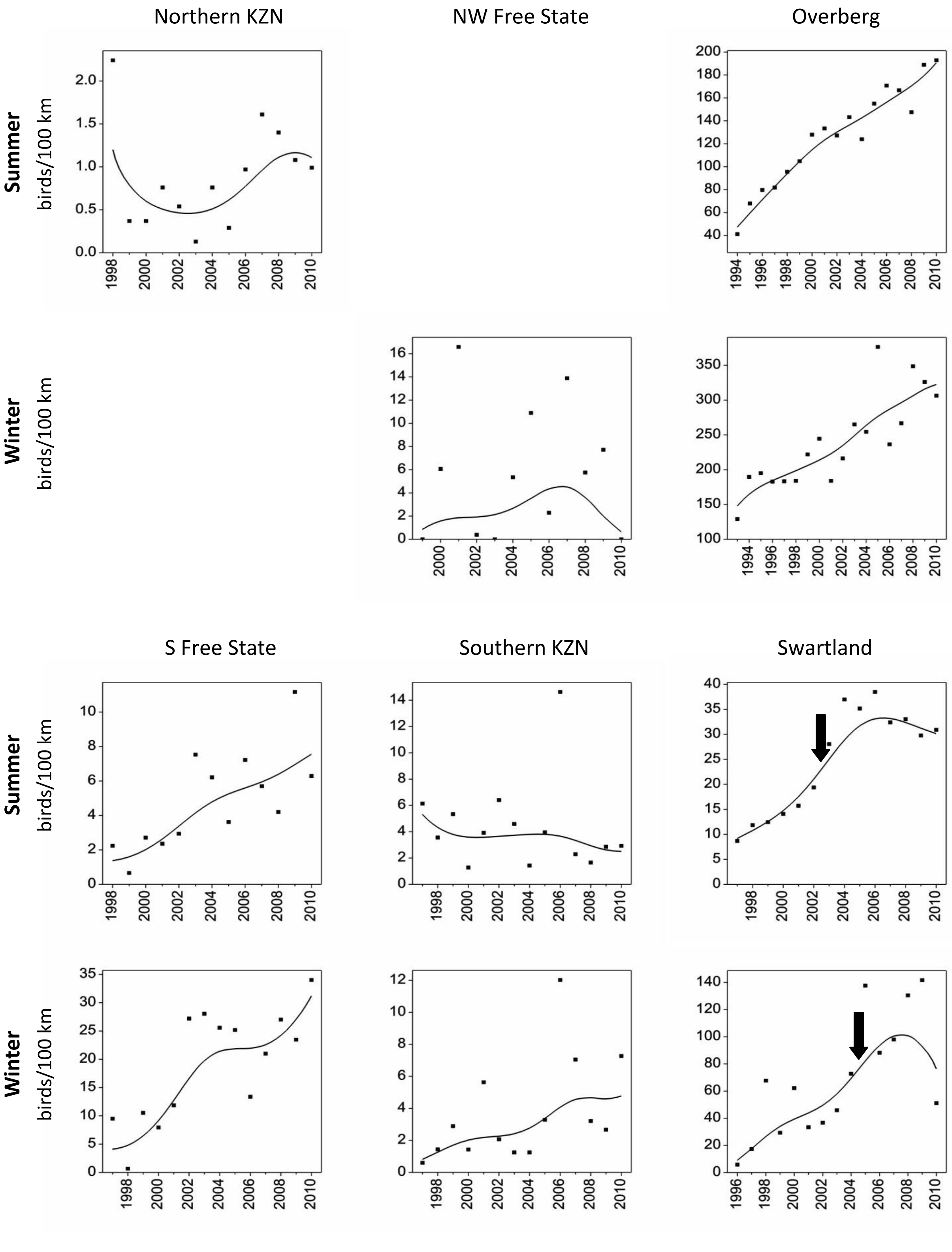


Figure 2b: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Blue Crane for the Northern KwaZulu-Natal (930 km), North-west Free State (1 270 km), Overberg (summer: 1 806 km; winter: 1 757 km), Southern Free State (summer: 5 052 km; winter: 4 511 km), Southern KwaZulu-Natal (1 123 km) and Swartland (summer: 938 km; winter: 980 km) precincts (Figure 1 in Chapter 1) for summer and winter counts. Arrows indicate relevant points of inflection in the trends, where the rate of change went from positive to negative.

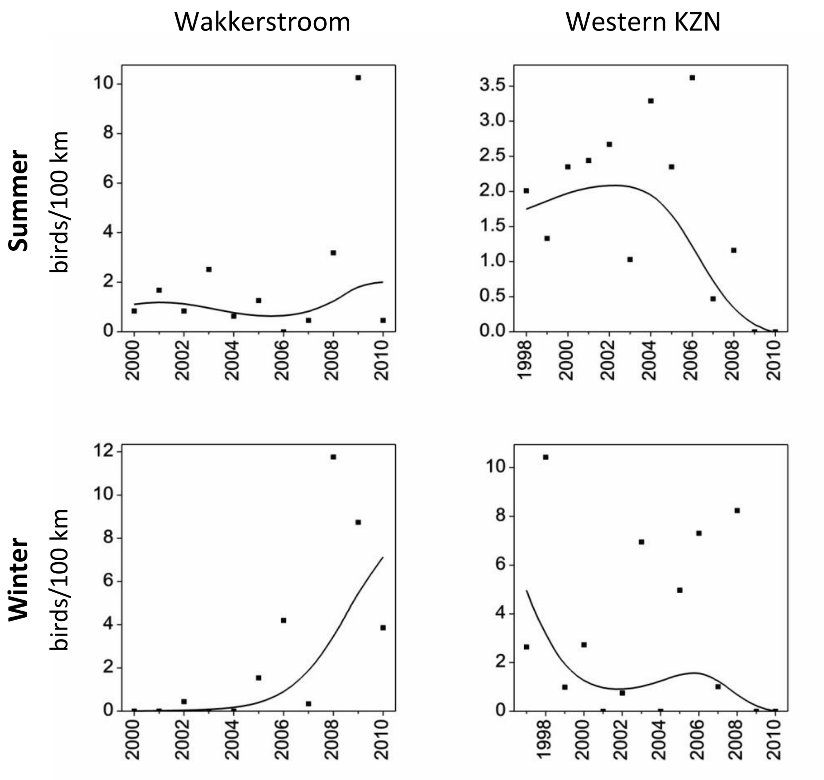


Figure 2c: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Blue Crane for the Wakkerstroom (summer: 489 km; winter: 595 km) and Western KwaZulu-Natal (summer: 450 km; winter: 403 km) precincts (Figure 1 in Chapter 1) for summer and winter counts.

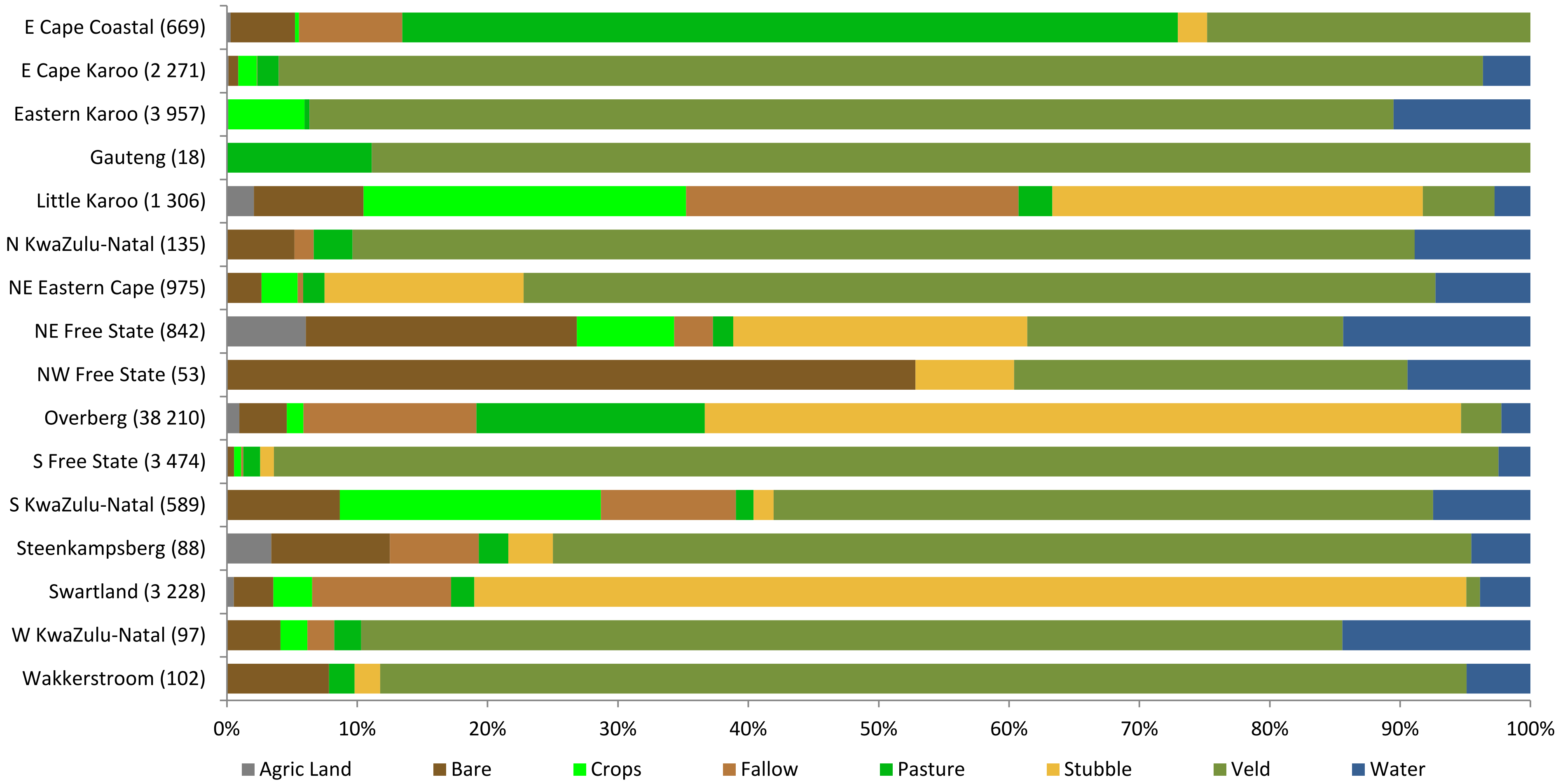


Figure 3a: CAR habitat use data for Blue Cranes for summer counts, for the sixteen precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in summer surveys. "Agric Land" includes burnt and mown land, feedlots and other miscellaneous types of farmland; "bare" indicates ploughed land, "crops" includes all cultivated crops, orchards and vineyards, and "stubble" is crop stubble.

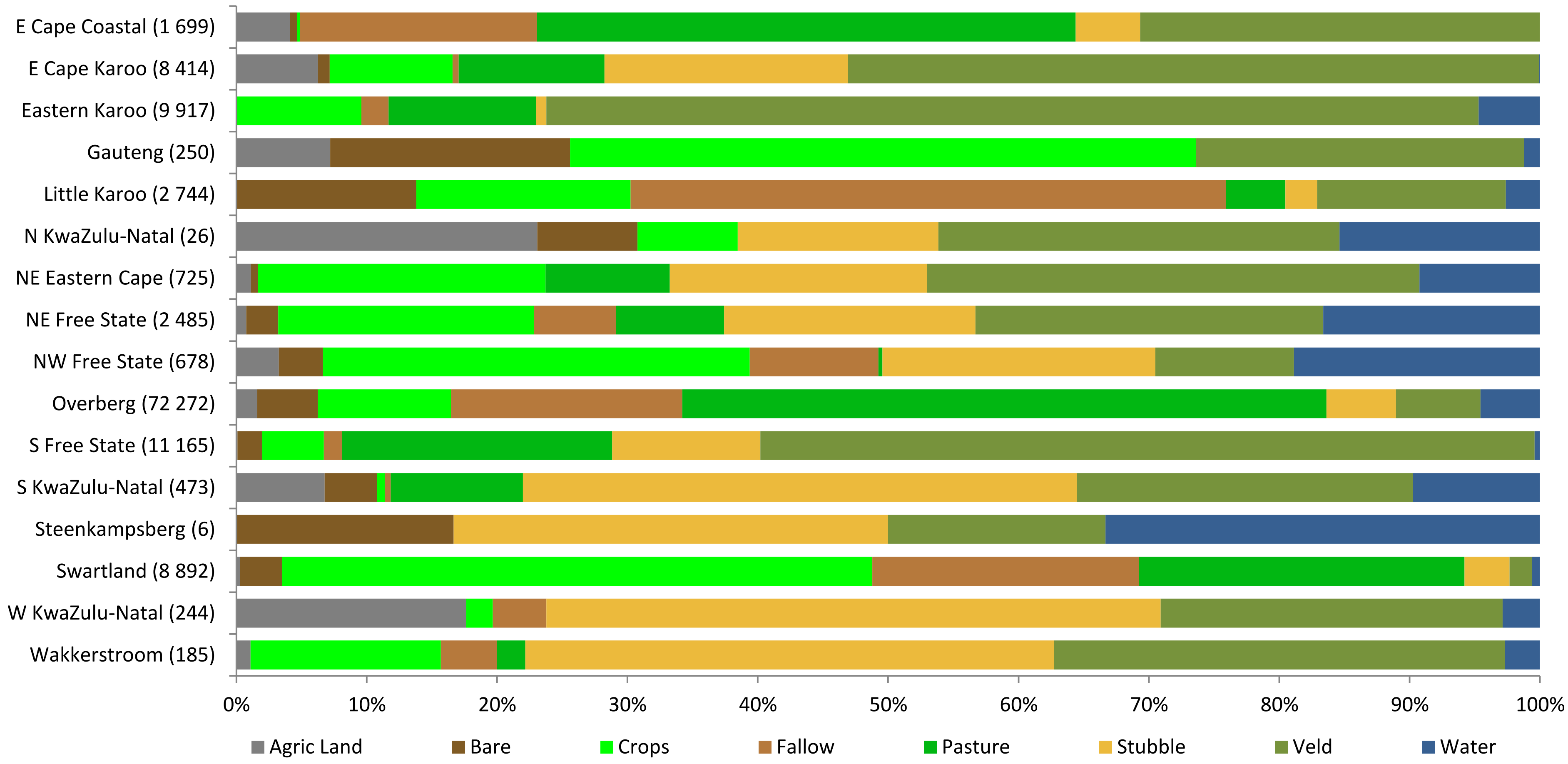


Figure 3b: CAR habitat use data for Blue Cranes for winter counts, for the sixteen precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in winter surveys. "Agric Land" includes burnt and mown land, feedlots and other miscellaneous types of farmland; "bare" indicates ploughed land, "crops" includes all cultivated crops, orchards and vineyards, and "stubble" is crop stubble.

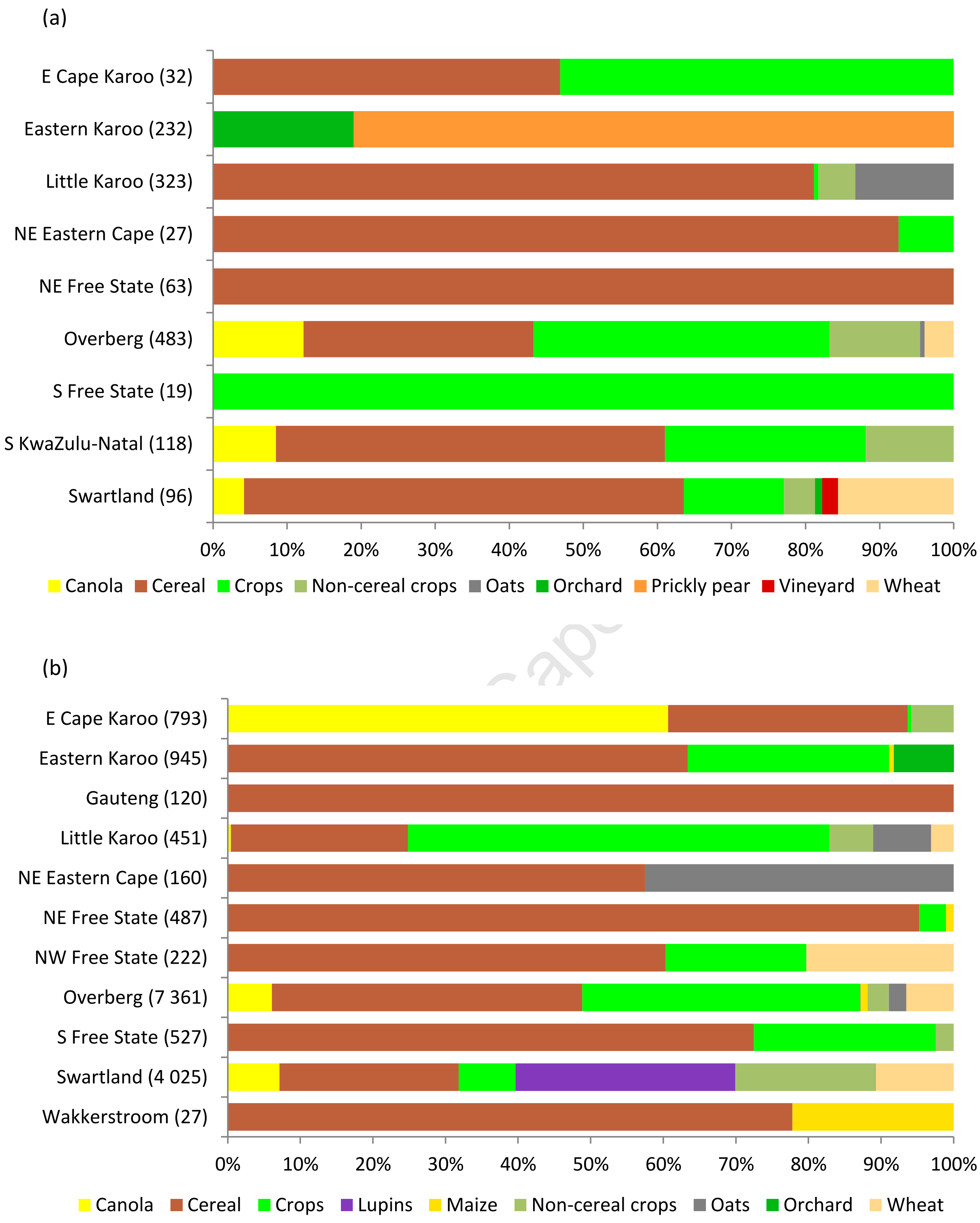


Figure 4: Break-down of Blue Crane crop habitat use data for (a) summer and (b) winter counts, showing the extent of occurrence in different types of crop fields for the precincts in which there were more than 10 birds observed in crop fields altogether. Numbers in brackets following the precinct name give the total number of birds recorded in crop habitats in that precinct in that season. Crop types were recorded where possible; where it was not possible to identify the type of crop but cereal crops could be distinguished from non-cereal, these were classified accordingly, but “Crops” was recorded if it was not obvious whether the crop was cereal or non-cereal.

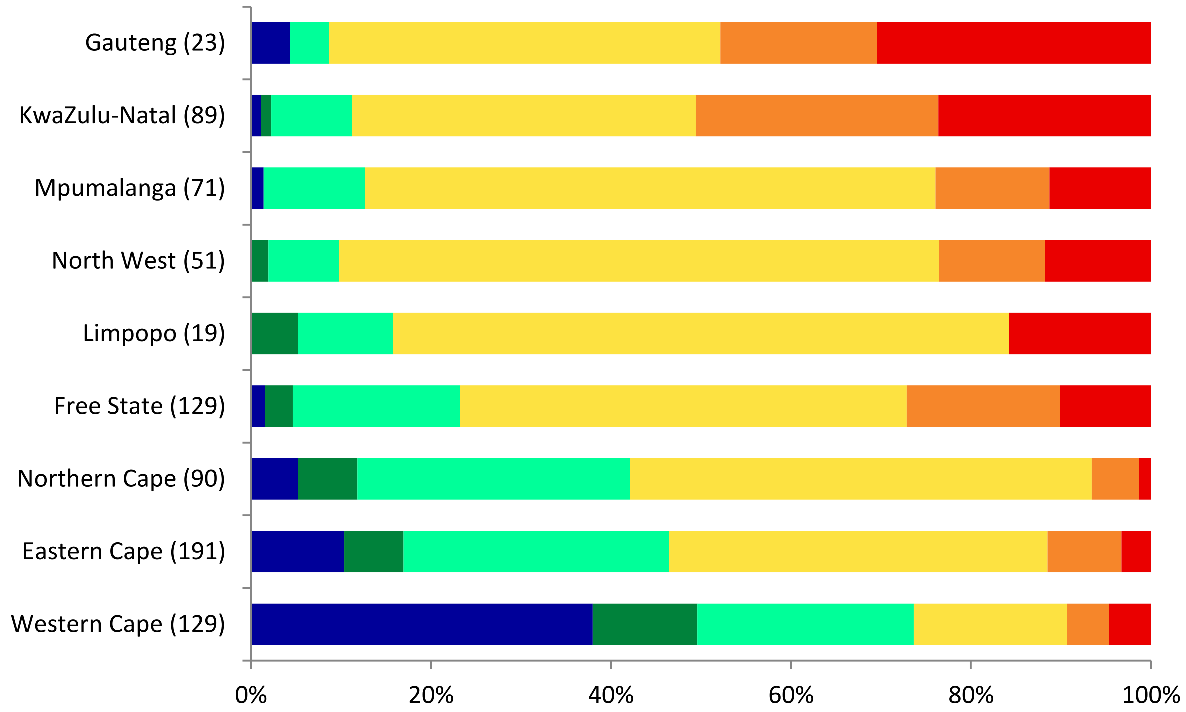
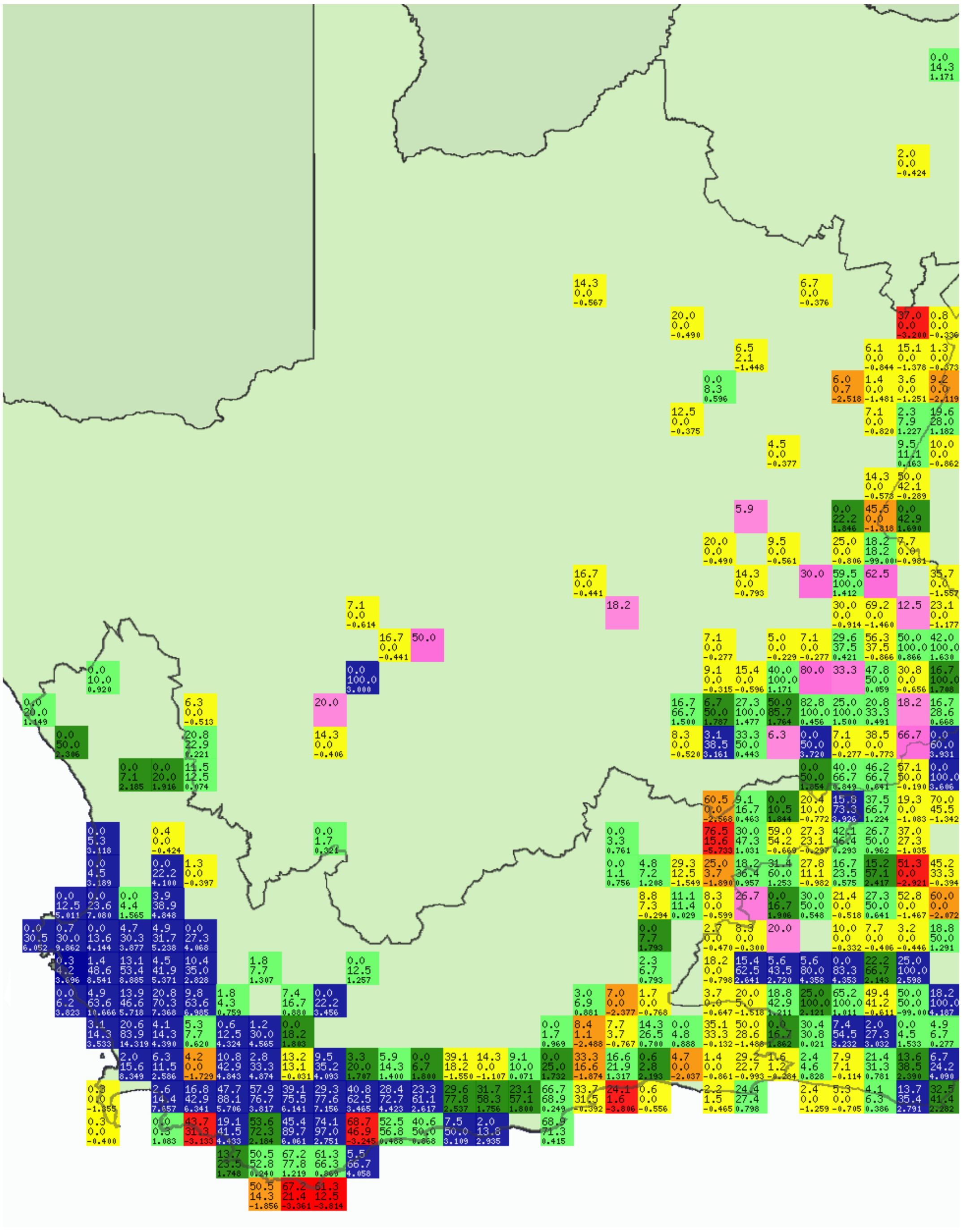
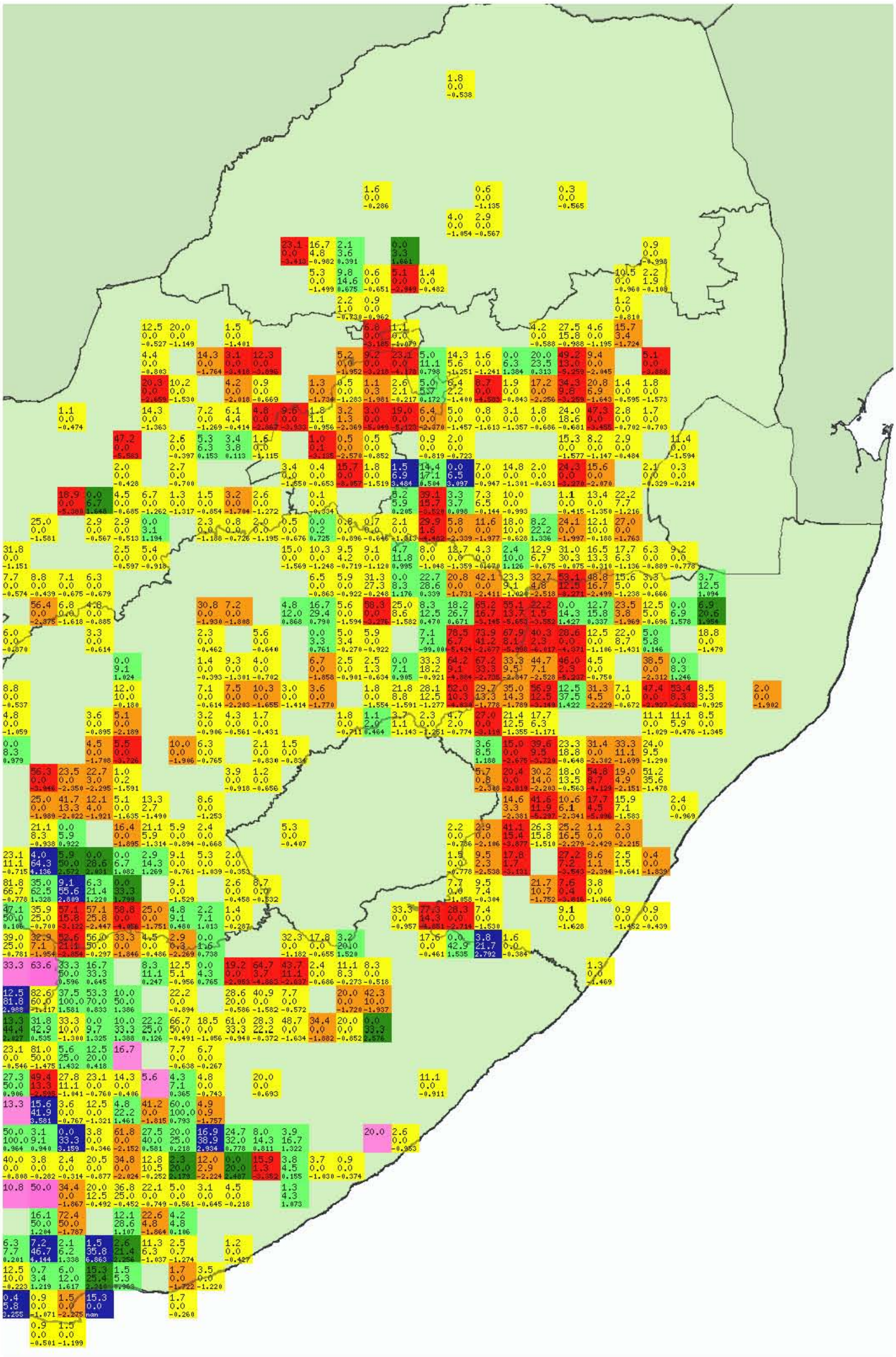


Figure 5: Numbers of quarter degree grid-cells (QDGCs) of different categories per province in the SABAP comparison map for the Blue Crane, extracted on 10 February 2012 (Figure 6). Numbers in brackets following the names of the provinces are the numbers of QDGCs in which Blue Cranes were ever recorded. Colours are coded as for QDGCs in Figure 6. SABAP2 reporting rates for were lower than SABAP1 in red, orange and yellow grid cells, and higher than SABAP1 in light and dark green and blue grid cells. In red grid cells $Z < -2.58$, in orange $-2.58 < Z < -1.64$, and in yellow $-1.64 < Z < 0$. In light green grid cells $0 \leq Z < 1.64$, in dark green $1.64 < Z < 2.58$, and in blue QDGCs $Z > 2.58$. Pink grid cells are those which had not yet been covered in SABAP2.

Figure 6: SABAP comparison map for the Blue Crane, extracted on 10 February 2012. This map compares SABAP1 and SABAP2 reporting rates. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15') in which the species was observed in either project. Reporting rates are compared using the *Z* statistic (see text). The upper number in each square is the SABAP1 reporting rate, the middle number is the SABAP2 reporting rate, and the lower number is *Z*. SABAP2 reporting rates for were lower than SABAP1 in red, orange and yellow grid cells, and higher than SABAP1 in light and dark green and blue grid cells. In red grid cells $Z < -2.58$, in orange $-2.58 < Z < -1.64$, and in yellow $-1.64 < Z < 0$. In light green grid cells $0 \leq Z < 1.64$, in dark green $1.64 < Z < 2.58$, and in blue grid cells $Z > 2.58$. Pink grid cells are those which had not yet been covered in SABAP2. Therefore, red, orange and yellow grid cells indicate areas of potential conservation concern, whereas green and blue grid cells indicate areas of apparent population increase.





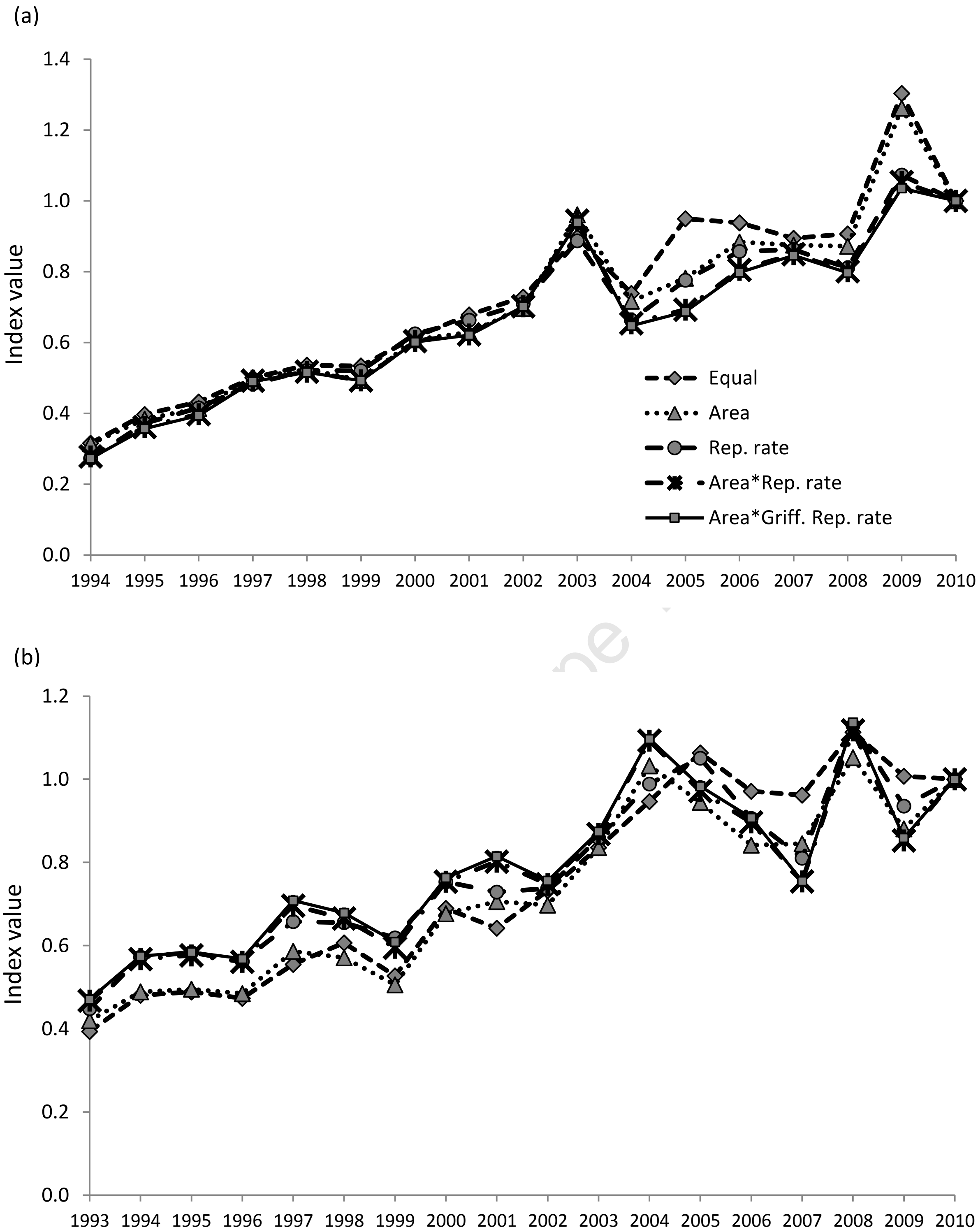


Figure 7: National population indices for Blue Cranes for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weights, each one represented by one set of points and a line. "Equal" had equal weights for each precinct. "Area" had precincts weighted by their relative area, and "Rep. rate" had precincts weighted by SABAP1 reporting rates for Southern Black Korhaans for that precinct. "Area*Rep. rate" weights used area and reporting rate multiplied together, and "Area*Griff. Rep. rate" used area multiplied by the logarithmic conversion of reporting rates suggested by Griffioen (2001).

Appendix 2. Supplementary data for Chapter 4

Table A2.1: Results of population trend analysis of CAR project data for Blue Cranes for 14 precincts in which the number of birds recorded attained the criteria for inclusion (see text): Eastern Cape Coastal, Eastern Cape Karoo, Eastern Karoo, Little Karoo, North-eastern Eastern Cape, North-eastern Free State, Northern KwaZulu-Natal, North-western Free State, Overberg, Southern Free State, Southern KwaZulu-Natal, Swartland, Wakkerstroom and Western KwaZulu-Natal. "Birds/100 km" columns show the count totals estimated using the Underhill index, converted to birds per 100 km of road surveyed; "incr" columns show the percent change in population per year, calculated as the slope of the weighted linear regressions; "Δ incr" columns show the change in increment from one year to the next (see text). At inflection points the Δ incr values change from negative to positive or vice versa. R^2 values give the proportion of the variance of the totals that is explained by the trend line; SD is the standard deviation of the totals, CV is the coefficient of variation, and "% imp" values indicate the percentage of the overall total that was imputed using the Underhill index. Distance gives the distance in kilometres of the routes included in each analysis. For uniformity, all results are presented to two decimal places.

	Eastern Cape Coastal					
Year	**Summer**			**Winter**		
	birds/100 km	**incr**	**Δ incr**	**birds/100 km**	**incr**	**Δ incr**
1998				0.00	1.02	
1999	7.98	0.30		0.00	1.14	0.12
2000	0.00	0.38	0.08	0.00	1.11	–0.03
2001	11.39	0.37	–0.01	7.57	0.92	–0.19
2002	15.95	0.29	–0.07	85.67	0.66	–0.26
2003	4.59	0.19	–0.10	22.97	0.44	–0.22
2004	8.65	0.08	–0.11	5.41	0.29	–0.15
2005	46.76	0.00	–0.08	45.94	0.18	–0.11
2006	3.24	–0.04	–0.04	110.00	0.07	–0.11
2007	9.15	–0.05	0.00	47.30	–0.04	–0.11
2008	5.68	–0.02	0.02	15.14	–0.11	–0.08
2009	14.86	0.00	0.03	27.30	–0.15	–0.04
2010	7.03	0.01	0.01	22.70	–0.15	0.00
Mean	11.27	0.13		30.00	0.41	
R^2	0.17			0.71		
SD	12.07			34.39		
CV	107.03			114.63		
% imp	23.28			1.18		
Distance (km)	370.01			370.01		

Eastern Cape Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				45.97	0.11	
1999	13.84	–0.11		20.39	0.11	0.00
2000	17.09	–0.08	0.03	77.88	0.11	–0.01
2001	8.22	–0.04	0.04	55.78	0.09	–0.01
2002	7.26	–0.01	0.03	34.42	0.07	–0.02
2003	11.78	0.01	0.02	61.02	0.04	–0.04
2004	17.82	0.03	0.01	130.65	–0.02	–0.05
2005	7.37	0.04	0.02	49.25	–0.07	–0.05
2006	11.29	0.07	0.02	45.90	–0.09	–0.02
2007	13.60	0.09	0.03	44.49	–0.09	0.00
2008	12.54	0.11	0.02	37.28	–0.06	0.03
2009	24.54	0.11	0.00	29.23	–0.01	0.05
2010	14.76	0.10	–0.02	64.71	0.05	0.06
Mean	13.34	0.03		53.61	0.02	
R^2	0.31			0.22		
SD	4.94			27.78		
CV	37.01			51.81		
% imp	12.72			18.37		
Distance (km)	1063.45			1012.55		

Eastern Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1995				21.93	0.32	
1996	7.97	0.16		23.74	0.26	–0.07
1997	23.53	0.10	–0.06	68.27	0.18	–0.07
1998	20.85	0.08	–0.02	71.07	0.13	–0.06
1999	13.63	0.09	0.01	46.42	0.09	–0.04
2000	14.90	0.11	0.02	42.85	0.06	–0.03
2001	17.33	0.11	0.00	99.64	0.04	–0.02
2002	33.62	0.07	–0.04	67.44	0.01	–0.03
2003	59.60	0.01	–0.06	50.85	–0.02	–0.03
2004	18.99	–0.03	–0.04	92.34	–0.04	–0.03
2005	14.09	–0.02	0.01	38.68	–0.07	–0.03
2006	17.00	0.03	0.05	96.42	–0.10	–0.03
2007	32.54	0.11	0.08	29.41	–0.14	–0.04
2008	36.71	0.19	0.08			
Mean	23.91	0.08		57.62	0.06	
R^2	0.38			0.45		
SD	13.75			27.13		
CV	57.52			47.08		
% imp	19.77			24.37		
Distance (km)	1115.38			1126.24		

Little Karoo

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
2000	12.71	–0.01		30.49	0.17	
2001	9.58	0.06	0.07	17.16	0.20	0.03
2002	8.44	0.13	0.07	20.47	0.19	0.00
2003	6.82	0.19	0.06	76.46	0.17	–0.02
2004	15.25	0.23	0.03	57.54	0.14	–0.03
2005	27.82	0.23	0.00	35.43	0.13	–0.01
2006	27.62	0.22	–0.01	33.86	0.14	0.00
2007	13.91	0.20	–0.02	136.72	0.13	0.00
2008	41.20	0.16	–0.03	71.90	0.12	–0.01
2009	93.16	0.10	–0.06	68.75	0.10	–0.02
2010	16.80	0.01	–0.09	93.16	0.08	–0.02
Mean	24.85	0.14		58.36	0.14	
R^2	0.56			0.53		
SD	24.90			36.07		
CV	100.23			61.80		
% imp	4.46			0.87		
Distance (km)	381.06			381.06		

North-eastern Eastern Cape

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1998				1.11	–0.05	
1999	1.51	0.49		0.00	0.08	0.13
2000	7.10	0.33	–0.17	2.21	0.21	0.13
2001	12.98	0.20	–0.13	0.00	0.35	0.13
2002	5.27	0.10	–0.10	2.51	0.45	0.11
2003	22.25	0.04	–0.06	0.11	0.47	0.02
2004	3.61	0.02	–0.02	10.32	0.36	–0.11
2005	11.85	0.03	0.01	1.61	0.20	–0.17
2006	6.54	0.05	0.02	18.54	0.07	–0.13
2007	12.67	0.06	0.01	0.20	0.05	–0.02
2008	10.52	0.05	–0.01	0.59	0.18	0.13
2009	13.71	0.02	–0.03	22.48	0.51	0.32
2010	8.20	–0.02	–0.04			
Mean	9.68	0.11		4.97	0.24	
R^2	0.40			0.26		
SD	5.57			7.83		
CV	57.51			157.40		
% imp	23.04			11.78		
Distance (km)	980.57			1035.02		

North-eastern Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998	1.57	0.38		9.49	0.05	
1999	0.63	0.43	0.05	4.36	0.18	0.12
2000	1.69	0.42	–0.02	1.19	0.24	0.06
2001	3.87	0.33	–0.08	17.30	0.21	–0.03
2002	9.73	0.21	–0.12	16.93	0.10	–0.11
2003	3.87	0.08	–0.13	23.65	–0.03	–0.13
2004	6.08	–0.02	–0.11	5.03	–0.14	–0.10
2005	3.72	–0.10	–0.08	9.56	–0.19	–0.05
2006	8.15	–0.15	–0.05	9.06	–0.18	0.01
2007	3.63	–0.16	–0.01	3.22	–0.09	0.09
2008	0.26	–0.13	0.03	0.21	0.08	0.17
2009	7.39	–0.07	0.06	12.81	0.34	0.26
2010	2.28	0.01	0.08	24.49	0.69	0.35
Mean	4.07	0.09		10.56	0.10	
R^2	0.33			0.30		
SD	2.97			8.06		
CV	72.92			76.27		
% imp	24.44			18.63		
Distance (km)	1789.85			1789.85		

Northern KwaZulu-Natal

Year	Summer		
	birds/100 km	incr	Δ incr
1998	2.24	–0.29	
1999	0.37	–0.22	0.07
2000	0.37	–0.16	0.06
2001	0.76	–0.10	0.06
2002	0.54	–0.04	0.06
2003	0.13	0.05	0.08
2004	0.76	0.15	0.10
2005	0.29	0.23	0.08
2006	0.97	0.25	0.02
2007	1.61	0.21	–0.04
2008	1.40	0.14	–0.07
2009	1.08	0.06	–0.08
2010	0.99	–0.01	–0.07
Mean	0.89	0.02	
R^2	0.46		
SD	0.60		
CV	67.32		
% imp	22.55		
Distance (km)	929.96		

North-western Free State

Year	Winter		
	birds/100 km	incr	Δ incr
1999	0.00	0.43	
2000	6.07	0.14	–0.29
2001	16.59	0.03	–0.11
2002	0.39	0.06	0.03
2003	0.00	0.17	0.11
2004	5.35	0.28	0.11
2005	10.90	0.28	0.00
2006	2.29	0.15	–0.12
2007	13.89	–0.03	–0.18
2008	5.76	–0.22	–0.19
2009	7.72	–0.39	–0.17
2010	0.00	–0.53	–0.14
Mean	5.75	0.03	
R^2	0.30		
SD	5.68		
CV	98.75		
% imp	23.85		
Distance (km)	1270.06		

Overberg

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1993				129.04	0.09	
1994	41.16	0.21		189.62	0.06	–0.03
1995	67.91	0.18	–0.03	195.10	0.05	–0.02
1996	79.66	0.15	–0.02	182.88	0.04	–0.01
1997	81.80	0.13	–0.02	183.37	0.03	0.00
1998	95.57	0.12	–0.02	184.07	0.04	0.00
1999	104.81	0.10	–0.02	221.94	0.04	0.00
2000	127.94	0.08	–0.02	244.49	0.04	0.00
2001	133.38	0.06	–0.02	184.04	0.04	0.01
2002	127.25	0.05	–0.01	216.24	0.05	0.01
2003	143.24	0.04	0.00	265.04	0.06	0.00
2004	123.97	0.04	0.00	254.47	0.05	–0.01
2005	155.02	0.05	0.00	376.41	0.04	–0.01
2006	170.76	0.04	0.00	236.43	0.03	–0.01
2007	166.65	0.04	0.00	266.73	0.03	0.00
2008	147.56	0.04	0.00	348.56	0.03	0.00
2009	188.93	0.05	0.01	326.04	0.03	0.00
2010	192.88	0.06	0.01	306.37	0.02	–0.01
Mean	126.38	0.08		239.49	0.04	
R^2	0.95			0.77		
SD	43.16			66.10		
CV	34.15			27.60		
% imp	7.39			3.33		
Distance (km)	1805.97			1757.19		

Southern Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1997				9.50	0.19	
1998	2.24	0.17		0.67	0.29	0.10
1999	0.66	0.24	0.06	10.54	0.35	0.06
2000	2.71	0.27	0.04	7.95	0.36	0.01
2001	2.36	0.27	0.00	11.87	0.32	–0.04
2002	2.94	0.24	–0.03	27.20	0.23	–0.09
2003	7.53	0.18	–0.06	28.05	0.12	–0.10
2004	6.21	0.12	–0.06	25.58	0.04	–0.08
2005	3.62	0.07	–0.04	25.18	0.00	–0.04
2006	7.22	0.06	–0.02	13.38	0.01	0.00
2007	5.70	0.06	0.00	21.00	0.04	0.03
2008	4.20	0.07	0.01	27.02	0.08	0.04
2009	11.17	0.08	0.01	23.47	0.11	0.03
2010	6.29	0.08	0.00	34.01	0.13	0.02
Mean	4.83	0.15		18.96	0.16	
R^2	0.67			0.64		
SD	2.86			9.79		
CV	59.16			51.65		
% imp	20.04			21.89		
Distance (km)	5052.35			4511.04		

Southern KwaZulu-Natal

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1997	6.14	–0.15		0.60	0.40	
1998	3.56	–0.11	0.04	1.44	0.29	–0.11
1999	5.34	–0.06	0.05	2.89	0.19	–0.10
2000	1.28	–0.01	0.05	1.43	0.10	–0.09
2001	3.92	0.01	0.03	5.63	0.04	–0.06
2002	6.41	0.02	0.01	2.07	0.04	0.00
2003	4.59	0.02	0.00	1.25	0.10	0.06
2004	1.43	0.01	–0.01	1.25	0.18	0.09
2005	3.96	–0.01	–0.02	3.29	0.22	0.04
2006	14.63	–0.06	–0.04	12.02	0.17	–0.05
2007	2.29	–0.10	–0.04	7.05	0.08	–0.09
2008	1.66	–0.12	–0.02	3.21	0.01	–0.07
2009	2.86	–0.10	0.01	2.67	–0.01	–0.02
2010	2.93	–0.06	0.04	7.27	0.02	0.03
Mean	4.36	–0.05		3.72	0.13	
R^2	0.12			0.50		
SD	3.38			3.21		
CV	77.64			86.19		
% imp	11.38			9.02		
Distance (km)	1122.98			1122.98		

Swartland

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1996				5.83	0.58	
1997	8.69	0.15		17.34	0.41	–0.16
1998	11.85	0.15	0.00	67.74	0.27	–0.14
1999	12.45	0.15	0.01	29.33	0.17	–0.10
2000	14.09	0.17	0.01	62.19	0.11	–0.06
2001	15.72	0.18	0.01	33.40	0.11	–0.01
2002	19.39	0.18	0.00	36.72	0.14	0.03
2003	28.06	0.16	–0.02	45.91	0.18	0.04
2004	36.98	0.12	–0.04	72.79	0.19	0.01
2005	35.17	0.07	–0.05	137.68	0.16	–0.03
2006	38.48	0.02	–0.05	88.22	0.11	–0.05
2007	32.40	–0.01	–0.03	98.00	0.05	–0.06
2008	33.04	–0.03	–0.02	130.45	–0.01	–0.06
2009	29.78	–0.03	–0.01	141.67	–0.07	–0.06
2010	30.91	–0.03	0.00	51.10	–0.13	–0.07
Mean	24.79	0.09		67.89	0.15	
R^2	0.95			0.78		
SD	10.55			43.45		
CV	42.58			63.99		
% imp	8.56			9.72		
Distance (km)	938.17			980.43		

Wakkerstroom

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
2000	0.84	0.02		0.00	0.59	
2001	1.68	–0.06	–0.08	0.00	0.57	–0.02
2002	0.84	–0.13	–0.07	0.44	0.66	0.09
2003	2.52	–0.19	–0.05	0.00	0.85	0.19
2004	0.63	–0.18	0.00	0.00	1.08	0.23
2005	1.26	–0.09	0.09	1.54	1.21	0.13
2006	0.00	0.10	0.19	4.20	1.17	–0.05
2007	0.46	0.34	0.24	0.34	1.00	–0.17
2008	3.19	0.49	0.15	11.76	0.80	–0.20
2009	10.26	0.44	–0.04	8.74	0.60	–0.19
2010	0.46	0.22	–0.22	3.86	0.41	–0.19
Mean	2.01	0.09		2.81	0.81	
R^2	0.19			0.70		
SD	2.90			4.04		
CV	143.95			143.89		
% imp	7.81			1.53		
Distance (km)	489.06			595.16		

Western KwaZulu-Natal

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1997				2.64	–0.36	
1998	2.01	0.06		10.43	–0.37	–0.02
1999	1.33	0.05	0.00	0.99	–0.34	0.03
2000	2.35	0.04	–0.01	2.73	–0.26	0.08
2001	2.44	0.02	–0.02	0.00	–0.12	0.14
2002	2.67	0.00	–0.02	0.75	0.04	0.16
2003	1.03	–0.03	–0.03	6.95	0.17	0.13
2004	3.29	–0.09	–0.06	0.00	0.22	0.05
2005	2.35	–0.19	–0.10	4.97	0.14	–0.08
2006	3.62	–0.30	–0.11	7.31	–0.05	–0.19
2007	0.47	–0.40	–0.10	1.01	–0.26	–0.22
2008	1.16	–0.48	–0.07	8.24	–0.45	–0.18
2009	0.00	–0.53	–0.05	0.00	–0.57	–0.13
2010	0.00	–0.55	–0.03	0.00	–0.65	–0.08
Mean	1.75	–0.18		3.29	–0.21	
R^2	0.78			0.33		
SD	1.18			3.60		
CV	67.65			109.64		
% imp	9.07			17.44		
Distance (km)	450.07			402.73		

Table A2.2: Habitat selection by Blue Cranes (BCs) using Coordinated Avifaunal Roadcounts (CAR) data, separated by precinct (Figure 1 in Chapter 1). "Land area" sections give the percentage of each type of land cover (natural or transformed) within a 3 000 m wide buffer zone around each route, as calculated from the National Land-Cover maps for 1994, 2000 and 2009 (NLC1994, NLC2000 and NLC2009 respectively). "No. BCs" gives numbers of birds seen in each habitat type on these routes over the whole count period (1993–2010). "Jacobs index" sections give the values calculated for this index; *r* is the proportion of birds seen in natural habitat to the total number of birds seen on that route, *p* is the proportion of the area of natural habitat to the total land area, calculated as the average of the three NLC values, and *D* is the index, calculated using the formula presented in Jacobs (1974). Positive values for *D* indicate selection for natural habitat, negative the reverse. The bottom row contains the overall percentages of each habitat type for each map, the percentage of birds seen in each habitat type, the total number of birds on which the analysis is based (underlined), and the Jacobs index values for the whole precinct (excluding routes on which the species was never seen).

Eastern Cape Coastal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EH01	62.55	37.45	70.80	29.20	66.17	33.83	48	25	73	0.66	0.67	–0.02
EH02	30.42	69.58	21.34	78.66	13.46	86.54	2	211	213	0.01	0.22	–0.93
EH03	27.98	72.02	16.40	83.60	11.78	88.22	8	30	38	0.21	0.19	0.07
EH04	70.42	29.58	71.01	28.99	64.49	35.51	0	8	8	0.00	0.69	–1.00
EH05	60.44	39.56	67.76	32.24	63.04	36.96	44	9	53	0.83	0.64	0.47
EH06	31.32	68.68	20.84	79.16	12.53	87.47	50	218	268	0.19	0.22	–0.09
EK01	89.63	10.37	94.95	5.05	86.02	13.98	2	0	2	1.00	0.90	1.00
EK02	75.91	24.09	90.97	9.03	70.71	29.29	12	2	14	0.86	0.79	0.22
Overall	55.71	44.29	56.01	43.99	47.50	52.50	24.81	75.19	669	0.25	0.53	–0.55

Eastern Cape Coastal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EH01	62.55	37.45	70.80	29.20	66.17	33.83	2	9	11	0.18	0.67	–0.80
EH02	30.42	69.58	21.34	78.66	13.46	86.54	2	277	279	0.01	0.22	–0.95
EH03	27.98	72.02	16.40	83.60	11.78	88.22	120	317	437	0.27	0.19	0.24
EH04	70.42	29.58	71.01	28.99	64.49	35.51	0	126	126	0.00	0.69	–1.00
EH05	60.44	39.56	67.76	32.24	63.04	36.96	25	56	81	0.31	0.64	–0.60
EH06	31.32	68.68	20.84	79.16	12.53	87.47	372	393	765	0.49	0.22	0.55
Overall	44.36	55.64	40.77	59.23	34.69	65.62	30.67	69.33	1699	0.31	0.40	–0.20

Eastern Cape Karoo summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EG01	98.52	1.48	99.88	0.12	98.80	1.20	23	0	23	1.00	0.99	1.00
EG02	94.55	5.45	99.03	0.97	98.13	1.87	48	0	48	1.00	0.97	1.00
EG03	98.15	1.85	99.02	0.98	98.17	1.83	29	0	29	1.00	0.98	1.00
EG04	93.20	6.80	93.58	6.37	93.97	6.03	3	0	3	1.00	0.94	1.00
EM01	96.98	3.02	95.57	4.43	98.36	1.64	75	0	75	1.00	0.97	1.00
EM02	96.83	3.17	92.89	7.11	98.27	1.73	4	0	4	1.00	0.96	1.00
EP01	88.94	11.06	87.41	12.59	97.76	2.24	485	0	485	1.00	0.91	1.00
EP02	99.28	0.72	98.25	1.75	98.27	1.73	125	0	125	1.00	0.99	1.00
EP03	98.88	1.12	90.69	9.31	97.01	2.99	51	0	51	1.00	0.96	1.00
EP04	99.78	0.22	91.13	8.87	98.18	1.82	27	0	27	1.00	0.96	1.00
EP05	100.00	0.00	99.51	0.49	99.10	0.90	5	0	5	1.00	1.00	1.00
EP06	87.10	12.90	71.07	28.93	81.88	18.12	10	17	27	0.37	0.80	–0.74
EP07	99.60	0.40	92.55	7.45	97.73	2.27	25	0	25	1.00	0.97	1.00
EP08	96.88	3.12	99.15	0.85	98.81	1.19	180	18	198	0.91	0.98	–0.70
EP10	96.94	3.06	78.07	21.93	96.56	3.44	47	2	49	0.96	0.91	0.42
EP11	67.10	32.90	69.17	30.83	66.80	33.20	12	17	29	0.41	0.68	–0.50
ES01	95.18	4.82	99.32	0.68	98.97	1.03	6	0	6	1.00	0.98	1.00
ES02	70.45	29.55	80.32	19.68	84.93	15.07	17	0	17	1.00	0.79	1.00
ES03	94.45	5.55	96.72	3.28	95.89	4.11	24	3	27	0.89	0.96	–0.47
ES04	96.73	3.27	97.31	2.69	97.02	2.98	168	0	168	1.00	0.97	1.00
ES05	93.27	6.73	94.34	5.66	90.25	9.75	13	0	13	1.00	0.93	1.00
ES07	97.95	2.05	99.44	0.56	98.63	1.37	53	0	53	1.00	0.99	1.00
ES08	94.13	5.87	92.65	7.35	97.65	2.35	359	31	390	0.92	0.95	–0.22
ES10	100.00	0.00	99.01	0.99	99.15	0.85	376	0	376	1.00	0.99	1.00
Overall	94.23	5.77	92.87	7.13	95.29	4.71	96.09	3.91	2253	0.96	0.94	0.21

Eastern Cape Karoo winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EG01	98.52	1.48	99.88	0.12	98.80	1.20	3	220	223	0.01	0.99	–1.00
EG02	94.55	5.45	99.03	0.97	98.13	1.87	40	0	40	1.00	0.97	1.00
EG03	98.15	1.85	99.02	0.98	98.17	1.83	9	2	11	0.82	0.98	–0.87
EG04	93.20	6.80	93.58	6.37	93.97	6.03	2	4	6	0.33	0.94	–0.93
EM01	96.98	3.02	95.57	4.43	98.36	1.64	215	2	217	0.99	0.97	0.54
EM02	96.83	3.17	92.89	7.11	98.27	1.73	4	0	4	1.00	0.96	1.00
EP01	88.94	11.06	87.41	12.59	97.76	2.24	387	0	387	1.00	0.91	1.00
EP02	99.28	0.72	98.25	1.75	98.27	1.73	1383	2	1385	1.00	0.99	0.82
EP03	98.88	1.12	90.69	9.31	97.01	2.99	124	186	310	0.40	0.96	–0.94
EP04	99.78	0.22	91.13	8.87	98.18	1.82	150	171	321	0.47	0.96	–0.94
EP05	100.00	0.00	99.51	0.49	99.10	0.90	1	0	1	1.00	1.00	1.00
EP06	87.10	12.90	71.07	28.93	81.88	18.12	0	1288	1288	0.00	0.80	–1.00
EP07	99.60	0.40	92.55	7.45	97.73	2.27	7	0	7	1.00	0.97	1.00
EP08	96.88	3.12	99.15	0.85	98.81	1.19	152	74	226	0.67	0.98	–0.93
EP09	73.37	26.63	63.44	36.56	74.98	25.02	0	457	457	0.00	0.71	–1.00
EP10	96.94	3.06	78.07	21.93	96.56	3.44	130	111	241	0.54	0.91	–0.78
ES01	95.18	4.82	99.32	0.68	98.97	1.03	6	0	6	1.00	0.98	1.00
ES02	70.45	29.55	80.32	19.68	84.93	15.07	3	166	169	0.02	0.79	–0.99
ES03	94.45	5.55	96.72	3.28	95.89	4.11	67	26	93	0.72	0.96	–0.79
ES04	96.73	3.27	97.31	2.69	97.02	2.98	26	249	275	0.09	0.97	–0.99
ES05	93.27	6.73	94.34	5.66	90.25	9.75	9	102	111	0.08	0.93	–0.99
ES06	95.08	4.92	99.09	0.91	96.80	3.20	23	0	23	1.00	0.97	1.00
ES07	97.95	2.05	99.44	0.56	98.63	1.37	4	0	4	1.00	0.99	1.00
ES08	94.13	5.87	92.65	7.35	97.65	2.35	339	534	873	0.39	0.95	–0.93
ES10	100.00	0.00	99.01	0.99	99.15	0.85	1376	319	1695	0.81	0.99	–0.95
Overall	94.80	5.20	93.47	6.53	95.95	4.05	53.27	46.73	8373	0.53	0.95	–0.88

Eastern Karoo summer												
	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK011	98.79	1.21	99.09	0.91	100.00	0.00	59	2	**61**	0.97	0.99	**–0.65**
NK012	99.00	1.00	98.41	1.59	99.87	0.13	61	0	**61**	1.00	0.99	**1.00**
NK013	99.39	0.61	98.82	1.18	100.00	0.00	71	0	**71**	1.00	0.99	**1.00**
NK021	100.00	0.00	97.63	2.37	99.97	0.03	31	0	**31**	1.00	0.99	**1.00**
NK022	96.58	3.42	88.53	11.47	100.00	0.00	7	0	**7**	1.00	0.95	**1.00**
NK023	96.25	3.75	90.53	9.47	100.00	0.00	105	0	**105**	1.00	0.96	**1.00**
NK031	99.40	0.60	97.28	2.72	100.00	0.00	50	0	**50**	1.00	0.99	**1.00**
NK032	99.03	0.97	98.83	1.17	100.00	0.00	149	28	**177**	0.84	0.99	**–0.93**
NK033	100.00	0.00	99.91	0.09	100.00	0.00	76	0	**76**	1.00	1.00	**1.00**
NK041	98.69	1.31	98.40	1.60	100.00	0.00	6	0	**6**	1.00	0.99	**1.00**
NK042	100.00	0.00	97.22	2.78	100.00	0.00	57	0	**57**	1.00	0.99	**1.00**
NK043	100.00	0.00	99.70	0.30	100.00	0.00	79	0	**79**	1.00	1.00	**1.00**
NK044	100.00	0.00	99.71	0.29	100.00	0.00	196	194	**390**	0.50	1.00	**–1.00**
NK051	97.91	2.09	99.91	0.09	99.98	0.02	15	0	**15**	1.00	0.99	**1.00**
NK052	99.94	0.06	100.00	0.00	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK053	99.71	0.29	99.06	0.94	99.93	0.07	17	0	**17**	1.00	1.00	**1.00**
NK061	99.83	0.17	99.97	0.03	100.00	0.00	690	0	**690**	1.00	1.00	**1.00**
NK062	99.67	0.33	99.98	0.02	100.00	0.00	319	32	**351**	0.91	1.00	**–0.98**
NK063	100.00	0.00	99.89	0.11	100.00	0.00	37	0	**37**	1.00	1.00	**1.00**
NK071	100.00	0.00	96.35	3.65	100.00	0.00	32	0	**32**	1.00	0.99	**1.00**
NK073	100.00	0.00	99.36	0.64	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK081	100.00	0.00	99.60	0.40	100.00	0.00	15	0	**15**	1.00	1.00	**1.00**
NK091	99.92	0.08	92.89	7.11	100.00	0.00	29	0	**29**	1.00	0.98	**1.00**
NK092	100.00	0.00	96.18	3.82	100.00	0.00	9	0	**9**	1.00	0.99	**1.00**
NK093	100.00	0.00	88.16	11.84	100.00	0.00	15	0	**15**	1.00	0.96	**1.00**
NK101	97.53	2.47	98.07	1.93	98.33	1.67	79	9	**88**	0.90	0.98	**–0.69**
NK102	99.07	0.93	99.59	0.41	99.58	0.42	14	0	**14**	1.00	0.99	**1.00**
NK111	98.81	1.19	97.29	2.71	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK132	99.83	0.17	100.00	0.00	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK141	99.78	0.22	99.92	0.08	99.93	0.07	22	0	**22**	1.00	1.00	**1.00**
NK142	99.79	0.21	99.30	0.70	99.62	0.38	25	0	**25**	1.00	1.00	**1.00**
NK143	99.95	0.05	99.97	0.03	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK161	100.00	0.00	88.77	11.23	99.68	0.32	6	0	**6**	1.00	0.96	**1.00**
NK162	99.91	0.09	98.75	1.25	100.00	0.00	8	0	**8**	1.00	1.00	**1.00**
NK171	100.00	0.00	99.96	0.04	100.00	0.00	10	0	**10**	1.00	1.00	**1.00**
NK173	100.00	0.00	99.98	0.02	99.99	0.01	63	0	**63**	1.00	1.00	**1.00**
NK181	99.97	0.03	98.43	1.57	98.95	1.05	36	0	**36**	1.00	0.99	**1.00**
NK182	99.45	0.55	94.79	5.21	97.03	2.97	28	0	**28**	1.00	0.97	**1.00**
NK183	99.85	0.15	96.83	3.17	97.27	2.73	26	0	**26**	1.00	0.98	**1.00**
NK202	99.20	0.80	99.79	0.21	100.00	0.00	5	0	**5**	1.00	1.00	**1.00**
NK203	100.00	0.00	99.90	0.10	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK211	100.00	0.00	92.41	7.59	100.00	0.00	4	0	**4**	1.00	0.97	**1.00**
NK221	98.63	1.37	96.25	3.75	100.00	0.00	6	0	**6**	1.00	0.98	**1.00**
NK222	100.00	0.00	98.97	1.03	99.98	0.02	12	0	**12**	1.00	1.00	**1.00**
NK223	100.00	0.00	98.28	1.72	100.00	0.00	7	2	**9**	0.78	0.99	**–0.96**
NK231	99.51	0.49	97.86	2.14	100.00	0.00	35	0	**35**	1.00	0.99	**1.00**
NK232	99.84	0.16	96.01	3.99	100.00	0.00	15	0	**15**	1.00	0.99	**1.00**
NK262	99.54	0.46	99.75	0.25	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK281	98.89	1.11	71.07	28.93	96.13	3.87	5	0	**5**	1.00	0.89	**1.00**
NK311	99.47	0.53	98.91	1.09	100.00	0.00	85	10	**95**	0.89	0.99	**–0.91**
NK312	100.00	0.00	97.90	2.10	99.96	0.04	24	0	**24**	1.00	0.99	**1.00**
NK313	98.41	1.59	99.82	0.18	100.00	0.00	12	0	**12**	1.00	0.99	**1.00**
NK321	93.38	6.62	91.83	8.17	99.80	0.20	33	0	**33**	1.00	0.95	**1.00**
NK322	98.38	1.62	97.53	2.47	100.00	0.00	6	0	**6**	1.00	0.99	**1.00**
NK323	96.24	3.76	96.13	3.87	99.98	0.02	52	0	**52**	1.00	0.97	**1.00**
NK331	100.00	0.00	96.49	3.51	99.32	0.68	11	0	**11**	1.00	0.99	**1.00**
NK332	100.00	0.00	90.80	9.20	100.00	0.00	70	0	**70**	1.00	0.97	**1.00**
NK333	100.00	0.00	99.77	0.23	100.00	0.00	41	0	**41**	1.00	1.00	**1.00**

NK341	99.71	0.29	99.54	0.46	99.55	0.45	18	0	**18**	1.00	1.00	**1.00**
NK342	98.20	1.80	98.63	1.37	98.57	1.43	8	0	**8**	1.00	0.98	**1.00**
NK343	98.15	1.85	98.57	1.43	98.71	1.29	17	0	**17**	1.00	0.98	**1.00**
NK351	97.22	2.78	99.83	0.17	99.98	0.02	61	0	**61**	1.00	0.99	**1.00**
NK352	99.42	0.58	99.97	0.03	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK353	100.00	0.00	99.97	0.03	100.00	0.00	105	0	**105**	1.00	1.00	**1.00**
NK361	100.00	0.00	98.02	1.98	100.00	0.00	35	0	**35**	1.00	0.99	**1.00**
NK362	100.00	0.00	97.56	2.44	99.96	0.04	73	4	**77**	0.95	0.99	**–0.74**
NK363	100.00	0.00	99.45	0.55	100.00	0.00	25	0	**25**	1.00	1.00	**1.00**
NK371	99.53	0.47	99.05	0.95	99.51	0.49	6	0	**6**	1.00	0.99	**1.00**
NK372	99.86	0.14	99.79	0.21	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK373	100.00	0.00	99.87	0.13	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK391	91.25	8.75	83.02	16.98	99.95	0.05	16	0	**16**	1.00	0.91	**1.00**
NK392	100.00	0.00	87.43	12.57	97.28	2.72	6	4	**10**	0.60	0.95	**–0.85**
NK393	99.88	0.12	98.65	1.35	99.88	0.12	19	0	**19**	1.00	0.99	**1.00**
NK431	100.00	0.00	99.41	0.59	100.00	0.00	18	0	**18**	1.00	1.00	**1.00**
NK441	96.90	3.10	87.01	12.99	95.24	4.76	14	0	**14**	1.00	0.93	**1.00**
NK442	92.09	7.91	82.36	17.64	100.00	0.00	26	0	**26**	1.00	0.91	**1.00**
NK443	92.91	7.09	74.87	25.13	99.11	0.89	55	0	**55**	1.00	0.89	**1.00**
NK451	95.25	4.75	87.29	12.71	99.99	0.01	18	0	**18**	1.00	0.94	**1.00**
NK452	98.27	1.73	98.39	1.61	99.76	0.24	3	0	**3**	1.00	0.99	**1.00**
NK453	97.54	2.46	95.40	4.60	100.00	0.00	10	0	**10**	1.00	0.98	**1.00**
Overall	**98.99**	**1.01**	**96.48**	**3.52**	**99.65**	**0.35**	**92.35**	**7.65**	**3726**	**0.92**	**0.98**	**–0.67**

Eastern Karoo winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
NK011	98.79	1.21	99.09	0.91	100.00	0.00	271	0	**271**	1.00	0.99	**1.00**
NK012	99.00	1.00	98.41	1.59	99.87	0.13	192	126	**318**	0.60	0.99	**–0.97**
NK013	99.39	0.61	98.82	1.18	100.00	0.00	99	9	**108**	0.92	0.99	**–0.88**
NK021	100.00	0.00	97.63	2.37	99.97	0.03	8	0	**8**	1.00	0.99	**1.00**
NK022	96.58	3.42	88.53	11.47	100.00	0.00	2	0	**2**	1.00	0.95	**1.00**
NK023	96.25	3.75	90.53	9.47	100.00	0.00	404	176	**580**	0.70	0.96	**–0.81**
NK031	99.40	0.60	97.28	2.72	100.00	0.00	109	0	**109**	1.00	0.99	**1.00**
NK032	99.03	0.97	98.83	1.17	100.00	0.00	427	84	**511**	0.84	0.99	**–0.93**
NK033	100.00	0.00	99.91	0.09	100.00	0.00	413	0	**413**	1.00	1.00	**1.00**
NK042	100.00	0.00	97.22	2.78	100.00	0.00	163	6	**169**	0.96	0.99	**–0.60**
NK043	100.00	0.00	99.70	0.30	100.00	0.00	393	0	**393**	1.00	1.00	**1.00**
NK044	100.00	0.00	99.71	0.29	100.00	0.00	369	0	**369**	1.00	1.00	**1.00**
NK051	97.91	2.09	99.91	0.09	99.98	0.02	53	0	**53**	1.00	0.99	**1.00**
NK053	99.71	0.29	99.06	0.94	99.93	0.07	27	0	**27**	1.00	1.00	**1.00**
NK061	99.83	0.17	99.97	0.03	100.00	0.00	522	25	**547**	0.95	1.00	**–0.97**
NK062	99.67	0.33	99.98	0.02	100.00	0.00	1053	0	**1053**	1.00	1.00	**1.00**
NK063	100.00	0.00	99.89	0.11	100.00	0.00	330	5	**335**	0.99	1.00	**–0.95**
NK071	100.00	0.00	96.35	3.65	100.00	0.00	8	0	**8**	1.00	0.99	**1.00**
NK081	100.00	0.00	99.60	0.40	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK083	100.00	0.00	99.90	0.10	99.98	0.02	11	0	**11**	1.00	1.00	**1.00**
NK091	99.92	0.08	92.89	7.11	100.00	0.00	4	0	**4**	1.00	0.98	**1.00**
NK093	100.00	0.00	88.16	11.84	100.00	0.00	60	0	**60**	1.00	0.96	**1.00**
NK101	97.53	2.47	98.07	1.93	98.33	1.67	191	246	**437**	0.44	0.98	**–0.97**
NK102	99.07	0.93	99.59	0.41	99.58	0.42	9	0	**9**	1.00	0.99	**1.00**
NK103	100.00	0.00	99.99	0.01	99.98	0.02	8	25	**33**	0.24	1.00	**–1.00**
NK141	99.78	0.22	99.92	0.08	99.93	0.07	241	5	**246**	0.98	1.00	**–0.89**
NK142	99.79	0.21	99.30	0.70	99.62	0.38	38	15	**53**	0.72	1.00	**–0.98**
NK171	100.00	0.00	99.96	0.04	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK173	100.00	0.00	99.98	0.02	99.99	0.01	58	0	**58**	1.00	1.00	**1.00**
NK181	99.97	0.03	98.43	1.57	98.95	1.05	30	0	**30**	1.00	0.99	**1.00**
NK182	99.45	0.55	94.79	5.21	97.03	2.97	359	0	**359**	1.00	0.97	**1.00**
NK183	99.85	0.15	96.83	3.17	97.27	2.73	20	9	**29**	0.69	0.98	**–0.91**

NK192	98.49	1.51	98.86	1.14	98.81	1.19	3	1	4	0.75	0.99	–0.93
NK202	99.20	0.80	99.79	0.21	100.00	0.00	150	18	168	0.89	1.00	–0.95
NK211	100.00	0.00	92.41	7.59	100.00	0.00	2	0	2	1.00	0.97	1.00
NK221	98.63	1.37	96.25	3.75	100.00	0.00	4	0	4	1.00	0.98	1.00
NK222	100.00	0.00	98.97	1.03	99.98	0.02	6	0	6	1.00	1.00	1.00
NK231	99.51	0.49	97.86	2.14	100.00	0.00	5	0	5	1.00	0.99	1.00
NK232	99.84	0.16	96.01	3.99	100.00	0.00	143	0	143	1.00	0.99	1.00
NK261	100.00	0.00	98.45	1.55	100.00	0.00	1	0	1	1.00	0.99	1.00
NK262	99.54	0.46	99.75	0.25	100.00	0.00	2	0	2	1.00	1.00	1.00
NK281	98.89	1.11	71.07	28.93	96.13	3.87	10	0	10	1.00	0.89	1.00
NK282	93.06	6.94	81.56	18.44	94.50	5.50	0	10	10	0.00	0.90	–1.00
NK283	97.87	2.13	97.37	2.63	98.34	1.66	2	0	2	1.00	0.98	1.00
NK311	99.47	0.53	98.91	1.09	100.00	0.00	64	0	64	1.00	0.99	1.00
NK312	100.00	0.00	97.90	2.10	99.96	0.04	25	0	25	1.00	0.99	1.00
NK313	98.41	1.59	99.82	0.18	100.00	0.00	1	0	1	1.00	0.99	1.00
NK321	93.38	6.62	91.83	8.17	99.80	0.20	6	0	6	1.00	0.95	1.00
NK322	98.38	1.62	97.53	2.47	100.00	0.00	46	0	46	1.00	0.99	1.00
NK323	96.24	3.76	96.13	3.87	99.98	0.02	41	0	41	1.00	0.97	1.00
NK341	99.71	0.29	99.54	0.46	99.55	0.45	9	300	309	0.03	1.00	–1.00
NK342	98.20	1.80	98.63	1.37	98.57	1.43	2	6	8	0.25	0.98	–0.99
NK343	98.15	1.85	98.57	1.43	98.71	1.29	146	170	316	0.46	0.98	–0.97
NK351	97.22	2.78	99.83	0.17	99.98	0.02	41	0	41	1.00	0.99	1.00
NK352	99.42	0.58	99.97	0.03	100.00	0.00	0	83	83	0.00	1.00	–1.00
NK353	100.00	0.00	99.97	0.03	100.00	0.00	5	0	5	1.00	1.00	1.00
NK361	100.00	0.00	98.02	1.98	100.00	0.00	57	0	57	1.00	0.99	1.00
NK363	100.00	0.00	99.45	0.55	100.00	0.00	9	0	9	1.00	1.00	1.00
NK371	99.53	0.47	99.05	0.95	99.51	0.49	6	0	6	1.00	0.99	1.00
NK372	99.86	0.14	99.79	0.21	100.00	0.00	112	0	112	1.00	1.00	1.00
NK373	100.00	0.00	99.87	0.13	100.00	0.00	2	0	2	1.00	1.00	1.00
NK391	91.25	8.75	83.02	16.98	99.95	0.05	58	0	58	1.00	0.91	1.00
NK392	100.00	0.00	87.43	12.57	97.28	2.72	56	127	183	0.31	0.95	–0.95
NK393	99.88	0.12	98.65	1.35	99.88	0.12	4	0	4	1.00	0.99	1.00
NK431	100.00	0.00	99.41	0.59	100.00	0.00	7	0	7	1.00	1.00	1.00
NK441	96.90	3.10	87.01	12.99	95.24	4.76	0	6	6	0.00	0.93	–1.00
NK442	92.09	7.91	82.36	17.64	100.00	0.00	0	16	16	0.00	0.91	–1.00
NK443	92.91	7.09	74.87	25.13	99.11	0.89	0	28	28	0.00	0.89	–1.00
NK451	95.25	4.75	87.29	12.71	99.99	0.01	6	0	6	1.00	0.94	1.00
NK452	98.27	1.73	98.39	1.61	99.76	0.24	4	0	4	1.00	0.99	1.00
NK453	97.54	2.46	95.40	4.60	100.00	0.00	38	0	38	1.00	0.98	1.00
Overall	**98.76**	**1.24**	**96.26**	**3.74**	**99.50**	**0.50**	**82.29**	**17.71**	**8445**	**0.82**	**0.98**	**–0.84**

Gauteng summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
GB04	72.59	27.41	57.97	42.03	51.68	48.32	0	2	2	0.00	0.61	–1.00
GB07	69.72	30.28	64.70	35.30	58.91	41.09	3	0	3	1.00	0.64	1.00
GD01	44.88	55.12	65.27	34.73	46.33	53.67	10	0	10	1.00	0.52	1.00
GW01	90.18	9.82	89.95	10.05	85.15	14.85	3	0	3	1.00	0.88	1.00
Overall	**67.73**	**32.27**	**69.21**	**30.79**	**59.68**	**40.32**	**88.89**	**11.11**	**18**	**0.89**	**0.66**	**0.62**

Gauteng winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
GB01	49.39	50.61	56.92	43.08	45.55	54.45	4	2	**6**	0.67	0.51	**0.32**
GB07	69.72	30.28	64.70	35.30	58.91	41.09	2	0	**2**	1.00	0.64	**1.00**
GD01	44.88	55.12	65.27	34.73	46.33	53.67	0	46	**46**	0.00	0.52	**-1.00**
GD03	69.16	30.84	87.22	12.78	76.60	23.40	56	16	**72**	0.78	0.78	**0.00**
GD04	51.66	48.34	59.78	40.22	46.03	53.97	0	120	**120**	0.00	0.52	**-1.00**
GD05	58.95	41.05	75.37	24.63	59.58	40.42	4	0	**4**	1.00	0.65	**1.00**
Overall	**57.19**	**42.81**	**68.21**	**31.79**	**55.13**	**44.87**	**26.40**	**73.60**	**250**	**0.26**	**0.60**	**-0.62**

Little Karoo summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
WC01	39.94	60.06	49.55	50.45	51.72	48.28	2	0	**2**	1.00	0.47	**1.00**
WC02	79.25	20.75	88.19	11.81	83.86	16.14	0	65	**65**	0.00	0.84	**–1.00**
WK03	69.60	30.40	69.83	30.17	61.49	38.51	0	37	**37**	0.00	0.67	**–1.00**
WK04	66.97	33.03	76.89	23.11	68.04	31.96	7	94	**101**	0.07	0.71	**–0.94**
WK05	52.63	47.37	67.69	32.31	55.24	44.76	0	3	**3**	0.00	0.59	**–1.00**
WU01	54.26	45.74	96.96	3.04	92.42	7.58	34	17	**51**	0.67	0.81	**–0.37**
WU02	74.19	25.81	95.08	4.92	78.95	21.05	7	546	**553**	0.01	0.83	**–0.99**
WU03	56.13	43.87	85.60	14.40	86.49	13.51	0	6	**6**	0.00	0.76	**–1.00**
WU04	59.35	40.65	87.58	12.42	70.68	29.32	0	19	**19**	0.00	0.73	**–1.00**
WU05	38.68	61.32	51.52	48.48	35.30	64.70	34	293	**327**	0.10	0.42	**–0.72**
WU06	49.20	50.80	67.92	32.08	61.59	38.41	2	3	**5**	0.40	0.60	**–0.38**
WU07	76.59	23.41	89.82	10.18	81.69	18.31	14	66	**80**	0.18	0.83	**–0.92**
Overall	**60.86**	**39.14**	**78.47**	**21.53**	**70.04**	**29.96**	**8.01**	**91.99**	**1249**	**0.08**	**0.70**	**–0.93**

Little Karoo winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
WC02	79.25	20.75	88.19	11.81	83.86	16.14	0	14	**14**	0.00	0.84	**–1.00**
WK01	53.46	46.54	68.38	31.62	60.95	39.05	6	20	**26**	0.23	0.61	**–0.68**
WK03	69.60	30.40	69.83	30.17	61.49	38.51	6	83	**89**	0.07	0.67	**–0.93**
WK04	66.97	33.03	76.89	23.11	68.04	31.96	0	265	**265**	0.00	0.71	**–1.00**
WU01	54.26	45.74	96.96	3.04	92.42	7.58	12	49	**61**	0.20	0.81	**–0.89**
WU02	74.19	25.81	95.08	4.92	78.95	21.05	163	458	**621**	0.26	0.83	**–0.86**
WU03	56.13	43.87	85.60	14.40	86.49	13.51	1	0	**1**	1.00	0.76	**1.00**
WU04	59.35	40.65	87.58	12.42	70.68	29.32	5	0	**5**	1.00	0.73	**1.00**
WU05	38.68	61.32	51.52	48.48	35.30	64.70	271	1323	**1594**	0.17	0.42	**–0.56**
WU06	49.20	50.80	67.92	32.08	61.59	38.41	0	2	**2**	0.00	0.60	**–1.00**
WU07	76.59	23.41	89.82	10.18	81.69	18.31	5	61	**66**	0.08	0.83	**–0.97**
Overall	**62.16**	**37.84**	**80.26**	**19.74**	**71.27**	**28.73**	**17.09**	**82.91**	**2744**	**0.17**	**0.71**	**–0.85**

North-eastern Eastern Cape summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EB01	84.41	15.59	89.73	10.27	88.72	11.28	11	0	**11**	1.00	0.88	**1.00**
EB02	90.91	9.09	92.87	7.13	90.69	9.31	2	0	**2**	1.00	0.91	**1.00**
EB03	90.03	9.97	83.01	16.99	77.48	22.52	39	2	**41**	0.95	0.84	**0.59**
EB04	93.78	6.22	95.75	4.25	93.50	6.50	16	0	**16**	1.00	0.94	**1.00**
EB05	89.05	10.95	80.33	19.67	76.58	23.42	9	2	**11**	0.82	0.82	**–0.01**
EE02	58.30	41.70	74.85	25.15	77.99	22.01	3	3	**6**	0.50	0.70	**–0.41**
EE07	86.28	13.72	84.75	15.25	77.25	22.75	0	2	**2**	0.00	0.83	**–1.00**
EE08	91.55	8.45	78.58	21.42	74.63	25.37	12	0	**12**	1.00	0.82	**1.00**
EE10	88.26	11.74	86.68	13.32	82.99	17.01	0	3	**3**	0.00	0.86	**–1.00**
EE11	94.86	5.14	92.82	7.18	90.14	9.86	23	30	**53**	0.43	0.93	**–0.88**
EE12	92.30	7.70	85.42	14.58	80.65	19.35	17	9	**26**	0.65	0.86	**–0.53**
EE13	81.38	18.62	86.98	13.02	79.70	20.30	1	0	**1**	1.00	0.83	**1.00**
EE14	83.73	16.27	84.25	15.75	77.32	22.68	12	41	**53**	0.23	0.82	**–0.88**
EE15	89.21	10.79	82.62	17.38	82.60	17.40	0	6	**6**	0.00	0.85	**–1.00**
EE18	82.50	17.50	88.13	11.87	77.45	22.55	84	99	**183**	0.46	0.83	**–0.70**
EE19	87.52	12.48	85.21	14.79	85.78	14.22	497	25	**522**	0.95	0.86	**0.52**
EQ02	97.22	2.78	46.60	53.40	39.27	60.73	27	0	**27**	1.00	0.61	**1.00**
Overall	**87.41**	**12.59**	**83.79**	**16.21**	**80.32**	**19.68**	**77.23**	**22.77**	**975**	**0.77**	**0.84**	**–0.21**

North-eastern Eastern Cape winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EB03	90.03	9.97	83.01	16.99	77.48	22.52	8	0	**8**	1.00	0.84	**1.00**
EE02	58.30	41.70	74.85	25.15	77.99	22.01	4	0	**4**	1.00	0.70	**1.00**
EE03	72.61	27.39	70.17	29.83	65.25	34.75	0	3	**3**	0.00	0.69	**–1.00**
EE04	75.54	24.46	75.76	24.24	73.21	26.79	4	2	**6**	0.67	0.75	**–0.20**
EE08	91.55	8.45	78.58	21.42	74.63	25.37	131	90	**221**	0.59	0.82	**–0.51**
EE11	94.86	5.14	92.82	7.18	90.14	9.86	0	1	**1**	0.00	0.93	**–1.00**
EE13	81.38	18.62	86.98	13.02	79.70	20.30	98	10	**108**	0.91	0.83	**0.34**
EE17	73.24	26.76	71.19	28.81	70.74	29.26	73	11	**84**	0.87	0.72	**0.45**
EE18	82.50	17.50	88.13	11.87	77.45	22.55	8	105	**113**	0.07	0.83	**–0.97**
EE19	87.52	12.48	85.21	14.79	85.78	14.22	15	125	**140**	0.11	0.86	**–0.96**
EQ01	96.38	3.62	54.10	45.90	48.75	51.25	0	34	**34**	0.00	0.66	**–1.00**
EQ02	97.22	2.78	46.60	53.40	39.27	60.73	0	3	**3**	0.00	0.61	**–1.00**
Overall	**84.11**	**15.89**	**76.16**	**23.84**	**72.45**	**27.55**	**47.03**	**52.97**	**725**	**0.47**	**0.78**	**–0.59**

North-eastern Free State summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EV01	99.22	0.78	91.24	8.76	97.85	2.15	4	0	**4**	1.00	0.96	**1.00**
FN11	43.35	56.65	59.96	40.04	48.23	51.77	0	72	**72**	0.00	0.51	**–1.00**
FN14	68.64	31.36	70.04	29.96	59.52	40.48	2	0	**2**	1.00	0.66	**1.00**
FN15	66.68	33.32	72.21	27.79	61.21	38.79	3	0	**3**	1.00	0.67	**1.00**
FN16	51.56	48.44	62.09	37.91	48.61	51.39	7	19	**26**	0.27	0.54	**–0.52**
FN17	69.53	30.47	77.89	22.11	67.71	32.29	2	0	**2**	1.00	0.72	**1.00**
FN18	80.96	19.04	86.93	13.07	80.33	19.67	0	16	**16**	0.00	0.83	**–1.00**
FN19	80.60	19.40	86.93	13.07	79.00	21.00	8	0	**8**	1.00	0.82	**1.00**
FN23	83.37	16.63	76.63	23.37	68.59	31.41	8	2	**10**	0.80	0.76	**0.11**
FN24	68.52	31.48	75.85	24.15	59.47	40.53	2	0	**2**	1.00	0.68	**1.00**
FN25	76.02	23.98	84.65	15.35	72.35	27.65	2	0	**2**	1.00	0.78	**1.00**
FN26	84.37	15.63	90.83	9.17	77.22	22.78	8	144	**152**	0.05	0.84	**–0.98**
FN28	90.14	9.86	93.06	6.94	80.80	19.20	32	0	**32**	1.00	0.88	**1.00**
FN29	86.64	13.36	93.38	6.62	85.80	14.20	1	6	**7**	0.14	0.89	**–0.96**
FN30	96.11	3.89	96.70	3.30	89.71	10.29	8	0	**8**	1.00	0.94	**1.00**
FN31	91.33	8.67	91.67	8.33	87.59	12.41	13	33	**46**	0.28	0.90	**–0.92**
FN32	93.84	6.16	96.96	3.04	92.73	7.27	22	6	**28**	0.79	0.95	**–0.65**
FN43	95.52	4.48	96.24	3.76	88.21	11.79	8	5	**13**	0.62	0.93	**–0.79**
FN45	79.64	20.36	83.53	16.47	78.71	21.29	13	53	**66**	0.20	0.81	**–0.89**
FN49	84.70	15.30	88.32	11.68	75.38	24.62	2	0	**2**	1.00	0.83	**1.00**
FN50	61.49	38.51	65.18	34.82	54.05	45.95	0	6	**6**	0.00	0.60	**–1.00**
FN52	27.83	72.17	46.56	53.44	32.84	67.16	137	149	**286**	0.48	0.36	**0.25**
FN53	84.70	15.30	78.77	21.23	69.64	30.36	6	2	**8**	0.75	0.78	**–0.07**
FN55	76.35	23.65	83.51	16.49	74.48	25.52	9	0	**9**	1.00	0.78	**1.00**
FN56	43.66	56.34	59.66	40.34	47.62	52.38	2	0	**2**	1.00	0.50	**1.00**
FN58	46.52	53.48	63.36	36.48	53.43	46.57	26	0	**26**	1.00	0.54	**1.00**
FN59	79.16	20.84	88.01	11.99	81.36	18.64	0	4	**4**	0.00	0.83	**–1.00**
Overall	**74.38**	**25.62**	**79.99**	**20.01**	**70.80**	**29.20**	**38.60**	**61.40**	**842**	**0.39**	**0.75**	**–0.65**

North-eastern Free State winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FN04	62.30	37.70	68.49	31.51	54.26	45.74	7	18	**25**	0.28	0.62	**-0.61**
FN11	43.35	56.65	59.96	40.04	48.23	51.77	0	2	**2**	0.00	0.51	**-1.00**
FN12	70.02	29.98	80.53	19.47	64.31	35.69	13	0	**13**	1.00	0.72	**1.00**
FN14	68.64	31.36	70.04	29.96	59.52	40.48	21	0	**21**	1.00	0.66	**1.00**
FN15	66.68	33.32	72.21	27.79	61.21	38.79	3	0	**3**	1.00	0.67	**1.00**
FN16	51.56	48.44	62.09	37.91	48.61	51.39	43	148	**191**	0.23	0.54	**-0.60**
FN19	80.60	19.40	86.93	13.07	79.00	21.00	33	25	**58**	0.57	0.82	**-0.55**
FN20	79.34	20.66	87.90	12.10	81.28	18.72	0	46	**46**	0.00	0.83	**-1.00**
FN22	82.86	17.14	83.55	16.45	74.15	25.85	110	4	**114**	0.96	0.80	**0.74**
FN24	68.52	31.48	75.85	24.15	59.47	40.53	0	23	**23**	0.00	0.68	**-1.00**
FN25	76.02	23.98	84.65	15.35	72.35	27.65	71	27	**98**	0.72	0.78	**-0.14**
FN26	84.37	15.63	90.83	9.17	77.22	22.78	0	25	**25**	0.00	0.84	**-1.00**
FN27	84.78	15.22	86.28	13.72	74.04	25.96	27	0	**27**	1.00	0.82	**1.00**
FN28	90.14	9.86	93.06	6.94	80.80	19.20	37	5	**42**	0.88	0.88	**0.00**
FN29	86.64	13.36	93.38	6.62	85.80	14.20	0	49	**49**	0.00	0.89	**-1.00**
FN30	96.11	3.89	96.70	3.30	89.71	10.29	0	3	**3**	0.00	0.94	**-1.00**
FN31	91.33	8.67	91.67	8.33	87.59	12.41	160	659	**819**	0.20	0.90	**-0.95**
FN32	93.84	6.16	96.96	3.04	92.73	7.27	0	20	**20**	0.00	0.95	**-1.00**
FN36	24.00	76.00	32.15	67.85	15.78	84.22	2	0	**2**	1.00	0.24	**1.00**
FN37	59.36	40.64	67.84	32.16	53.50	46.50	0	1	**1**	0.00	0.60	**-1.00**
FN40	21.66	78.34	43.02	56.98	29.19	70.81	3	4	**7**	0.43	0.31	**0.24**
FN45	79.64	20.36	83.53	16.47	78.71	21.29	4	8	**12**	0.33	0.81	**-0.79**
FN49	84.70	15.30	88.32	11.68	75.38	24.62	57	140	**197**	0.29	0.83	**-0.84**
FN52	27.83	72.17	46.56	53.44	32.84	67.16	267	21	**288**	0.93	0.36	**0.92**
FN55	76.35	23.65	83.51	16.49	74.48	25.52	131	25	**156**	0.84	0.78	**0.19**
FN56	43.66	56.34	59.66	40.34	47.62	52.38	0	2	**2**	0.00	0.50	**-1.00**
FN58	46.52	53.48	63.36	36.48	53.43	46.57	87	154	**241**	0.36	0.54	**-0.36**
Overall	**68.36**	**31.64**	**76.00**	**24.00**	**65.05**	**34.95**	**43.30**	**56.70**	**2485**	**0.43**	**0.70**	**-0.50**

Northern KwaZulu-Natal summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD02	90.63	9.37	42.52	57.48	81.19	18.81	11	0	**11**	1.00	0.71	**1.00**
KD08	73.77	26.23	47.10	52.90	65.28	34.72	2	7	**9**	0.22	0.62	**–0.70**
KD12	53.59	46.41	35.89	64.11	46.91	53.09	4	0	**4**	1.00	0.45	**1.00**
KL10	68.60	31.40	83.83	16.17	80.97	19.03	1	0	**1**	1.00	0.78	**1.00**
KN04	69.89	30.11	78.67	21.33	70.79	29.21	5	0	**5**	1.00	0.73	**1.00**
KN06	90.34	9.66	95.83	4.17	90.66	9.34	15	0	**15**	1.00	0.92	**1.00**
KN07	89.84	10.16	77.07	22.93	82.82	17.18	8	0	**8**	1.00	0.83	**1.00**
KN08	90.15	9.85	88.17	11.83	86.16	13.84	48	0	**48**	1.00	0.88	**1.00**
KO01	83.35	16.65	62.28	37.72	69.53	30.47	4	0	**4**	1.00	0.72	**1.00**
KV01	64.93	35.07	42.89	57.10	58.82	41.18	5	0	**5**	1.00	0.56	**1.00**
KV02	88.79	11.21	67.00	33.00	74.78	25.22	9	6	**15**	0.60	0.77	**–0.38**
KV04	99.06	0.94	93.26	6.74	80.09	19.91	10	0	**10**	1.00	0.91	**1.00**
Overall	**80.09**	**19.91**	**66.08**	**33.92**	**73.70**	**26.30**	**90.37**	**9.63**	**135**	**0.90**	**0.73**	**0.55**

Northern KwaZulu-Natal winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD02	90.63	9.37	42.52	57.48	81.19	18.81	8	6	**14**	0.57	0.71	**–0.30**
KD03	73.19	26.81	63.50	36.50	71.00	29.00	2	0	**2**	1.00	0.69	**1.00**
KL10	68.60	31.40	83.83	16.17	80.97	19.03	0	4	**4**	0.00	0.78	**–1.00**
KN01	92.39	7.61	95.58	4.42	87.95	12.05	2	0	**2**	1.00	0.92	**1.00**
KN03	72.35	27.65	81.62	18.38	65.49	34.51	0	2	**2**	0.00	0.73	**–1.00**
KV01	64.93	35.07	42.89	57.10	58.82	41.18	0	2	**2**	0.00	0.56	**–1.00**
Overall	**77.19**	**22.81**	**64.96**	**35.04**	**72.81**	**27.19**	**46.15**	**53.85**	**26**	**0.46**	**0.72**	**–0.49**

North-western Free State summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FW19	31.49	68.51	46.04	53.96	27.22	72.78	0	7	**7**	0.00	0.35	**–1.00**
FW26	61.78	38.22	71.95	28.05	51.44	48.56	3	0	**3**	1.00	0.62	**1.00**
FW45	54.01	45.99	60.31	39.69	45.30	54.70	1	0	**1**	1.00	0.53	**1.00**
FW46	91.65	8.35	89.55	10.45	76.31	23.69	8	25	**33**	0.24	0.86	**–0.90**
FW51	77.02	22.98	73.25	26.75	65.97	34.03	9	0	**9**	1.00	0.72	**1.00**
Overall	**62.50**	**37.50**	**67.54**	**32.46**	**52.84**	**47.16**	**39.62**	**60.38**	**53**	**0.40**	**0.61**	**–0.41**

North-western Free State winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FW01	27.06	72.94	48.39	51.61	33.52	66.48	2	0	**2**	1.00	0.36	**1.00**
FW07	46.52	53.48	58.73	41.27	45.33	54.67	0	1	**1**	0.00	0.50	**–1.00**
FW08	83.77	16.23	79.88	20.12	69.78	30.22	0	2	**2**	0.00	0.78	**–1.00**
FW19	31.49	68.51	46.04	53.96	27.22	72.78	1	0	**1**	1.00	0.35	**1.00**
FW26	61.78	38.22	71.95	28.05	51.44	48.56	3	3	**6**	0.50	0.62	**–0.23**
FW30	28.78	71.22	43.69	56.31	21.57	78.43	10	0	**10**	1.00	0.31	**1.00**
FW46	91.65	8.35	89.55	10.45	76.31	23.69	60	170	**230**	0.26	0.86	**–0.89**
FW51	77.02	22.98	73.25	26.75	65.97	34.03	124	229	**353**	0.35	0.72	**–0.65**
FW52	35.04	64.96	41.39	58.61	29.00	71.00	0	73	**73**	0.00	0.35	**–1.00**
Overall	**52.21**	**47.79**	**60.52**	**39.48**	**45.66**	**54.34**	**29.50**	**70.50**	**678**	**0.29**	**0.53**	**–0.46**

	Overberg summer											
	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
OV01	5.87	94.13	15.04	84.96	3.32	96.68	241	1335	**1576**	0.15	0.08	**0.35**
OV02	11.48	88.52	16.83	83.17	4.11	95.89	154	877	**1031**	0.15	0.11	**0.18**
OV03	35.26	64.74	40.32	59.68	30.17	69.83	16	1352	**1368**	0.01	0.35	**–0.96**
OV04	20.45	79.55	18.98	81.02	8.25	91.75	123	535	**658**	0.19	0.16	**0.10**
OV05	15.54	84.46	20.00	80.00	5.13	94.87	25	1807	**1832**	0.01	0.14	**–0.84**
OV06	19.50	80.50	21.56	78.44	7.50	92.50	69	1152	**1221**	0.06	0.16	**–0.53**
OV07	9.42	90.58	15.91	84.09	3.71	96.29	42	1863	**1905**	0.02	0.10	**–0.65**
OV08	18.08	81.92	12.90	87.10	5.38	94.62	20	1772	**1792**	0.01	0.12	**–0.85**
OV09	6.59	93.41	12.79	87.21	3.28	96.72	27	2790	**2817**	0.01	0.08	**–0.79**
OV10	2.27	97.73	8.38	91.62	1.83	98.17	34	902	**936**	0.04	0.04	**–0.07**
OV11	66.86	33.14	50.08	49.92	38.87	61.13	100	1649	**1749**	0.06	0.52	**–0.89**
OV12	49.73	50.26	30.61	69.39	23.04	76.96	51	1231	**1282**	0.04	0.34	**–0.85**
OV13	16.61	83.39	21.01	78.99	5.26	94.74	111	2509	**2620**	0.04	0.14	**–0.58**
OV14	15.01	84.99	23.40	76.60	8.26	91.74	156	1476	**1632**	0.10	0.16	**–0.27**
OV15	10.40	89.60	14.02	85.98	3.75	96.25	120	1352	**1472**	0.08	0.09	**–0.08**
OV16	10.66	89.34	11.11	88.89	4.85	95.15	12	1076	**1088**	0.01	0.09	**–0.79**
OV17	45.40	54.60	54.19	45.81	32.40	67.60	36	1648	**1684**	0.02	0.44	**–0.95**
OV18	31.88	68.12	28.95	71.05	16.91	83.09	108	3152	**3260**	0.03	0.26	**–0.82**
OV19	12.12	87.88	16.26	83.74	3.95	96.05	55	821	**876**	0.06	0.11	**–0.29**
OV20	8.59	91.41	12.15	87.85	1.44	98.56	25	626	**651**	0.04	0.07	**–0.33**
OV21	19.79	80.21	16.20	83.80	3.22	96.78	74	989	**1063**	0.07	0.13	**–0.34**
OV22	27.77	72.23	21.32	78.68	9.95	90.05	33	613	**646**	0.05	0.20	**–0.64**
OV23	27.95	72.05	28.83	71.17	13.67	86.33	0	52	**52**	0.00	0.23	**–1.00**
OV24	67.05	32.95	47.99	52.01	36.26	63.74	40	945	**985**	0.04	0.50	**–0.92**
OV25	30.18	69.82	40.58	59.42	25.67	74.33	2	446	**448**	0.00	0.32	**–0.98**
OV26	38.09	61.91	47.09	52.91	29.57	70.43	56	592	**648**	0.09	0.38	**–0.74**
OV27	44.97	55.03	48.35	51.65	34.19	65.81	35	186	**221**	0.16	0.43	**–0.59**
OV28	60.37	39.63	48.95	51.05	36.56	63.44	28	59	**87**	0.32	0.49	**–0.33**
OV29	55.84	44.16	43.32	56.68	25.30	74.70	17	88	**105**	0.16	0.41	**–0.57**
OV30	11.79	88.21	22.09	77.91	10.28	89.72	5	11	**16**	0.31	0.15	**0.45**
OV31	15.11	84.89	22.14	77.86	4.60	95.40	0	40	**40**	0.00	0.14	**–1.00**
OV32	1.12	98.88	5.70	94.30	0.18	99.82	0	98	**98**	0.00	0.02	**–1.00**
OV33	60.75	39.25	42.33	57.67	28.09	71.91	92	317	**409**	0.22	0.44	**–0.46**
OV34	75.78	24.22	96.34	3.66	91.43	8.57	22	49	**71**	0.31	0.88	**–0.88**
OV35	33.42	66.58	42.21	57.79	32.00	68.00	0	242	**242**	0.00	0.36	**–1.00**
OV36	25.34	74.66	31.51	68.49	21.07	78.93	13	971	**984**	0.01	0.26	**–0.93**
OV37	39.58	60.42	52.64	47.36	35.96	64.04	88	378	**466**	0.19	0.43	**–0.52**
WK02	39.72	60.28	57.66	42.34	40.26	59.74	6	189	**195**	0.03	0.46	**–0.93**
Overall	**27.78**	**72.22**	**29.46**	**70.54**	**17.22**	**82.78**	**5.33**	**94.67**	**38226**	**0.05**	**0.25**	**–0.71**

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
					Overberg winter							
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
OV01	5.87	94.13	15.04	84.96	3.32	96.68	699	1639	2338	0.30	0.08	0.66
OV02	11.48	88.52	16.83	83.17	4.11	95.89	747	713	1460	0.51	0.11	0.79
OV03	35.26	64.74	40.32	59.68	30.17	69.83	27	917	944	0.03	0.35	–0.90
OV04	20.45	79.55	18.98	81.02	8.25	91.75	263	2847	3110	0.08	0.16	–0.34
OV05	15.54	84.46	20.00	80.00	5.13	94.87	48	2382	2430	0.02	0.14	–0.77
OV06	19.50	80.50	21.56	78.44	7.50	92.50	43	1727	1770	0.02	0.16	–0.77
OV07	9.42	90.58	15.91	84.09	3.71	96.29	39	3913	3952	0.01	0.10	–0.83
OV08	18.08	81.92	12.90	87.10	5.38	94.62	80	10826	10906	0.01	0.12	–0.90
OV09	6.59	93.41	12.79	87.21	3.28	96.72	3400	4148	7548	0.45	0.08	0.82
OV10	2.27	97.73	8.38	91.62	1.83	98.17	65	1144	1209	0.05	0.04	0.13
OV11	66.86	33.14	50.08	49.92	38.87	61.13	47	287	334	0.14	0.52	–0.74
OV12	49.73	50.26	30.61	69.39	23.04	76.96	80	2911	2991	0.03	0.34	–0.90
OV13	16.61	83.39	21.01	78.99	5.26	94.74	935	5616	6551	0.14	0.14	0.00
OV14	15.01	84.99	23.40	76.60	8.26	91.74	79	4777	4856	0.02	0.16	–0.84
OV15	10.40	89.60	14.02	85.98	3.75	96.25	657	2582	3239	0.20	0.09	0.42
OV16	10.66	89.34	11.11	88.89	4.85	95.15	81	5186	5267	0.02	0.09	–0.72
OV17	45.40	54.60	54.19	45.81	32.40	67.60	11	1573	1584	0.01	0.44	–0.98
OV18	31.88	68.12	28.95	71.05	16.91	83.09	29	3011	3040	0.01	0.26	–0.95
OV19	12.12	87.88	16.26	83.74	3.95	96.05	229	1143	1372	0.17	0.11	0.25
OV20	8.59	91.41	12.15	87.85	1.44	98.56	65	2262	2327	0.03	0.07	–0.47
OV21	19.79	80.21	16.20	83.80	3.22	96.78	22	472	494	0.04	0.13	–0.53
OV22	27.77	72.23	21.32	78.68	9.95	90.05	85	1365	1450	0.06	0.20	–0.59
OV23	27.95	72.05	28.83	71.17	13.67	86.33	2	26	28	0.07	0.23	–0.60
OV24	67.05	32.95	47.99	52.01	36.26	63.74	6	238	244	0.02	0.50	–0.95
OV25	30.18	69.82	40.58	59.42	25.67	74.33	0	164	164	0.00	0.32	–1.00
OV26	38.09	61.91	47.09	52.91	29.57	70.43	9	269	278	0.03	0.38	–0.90
OV27	44.97	55.03	48.35	51.65	34.19	65.81	15	68	83	0.18	0.43	–0.54
OV28	60.37	39.63	48.95	51.05	36.56	63.44	13	27	40	0.33	0.49	–0.33
OV29	55.84	44.16	43.32	56.68	25.30	74.70	6	273	279	0.02	0.41	–0.94
OV30	11.79	88.21	22.09	77.91	10.28	89.72	12	180	192	0.06	0.15	–0.44
OV31	15.11	84.89	22.14	77.86	4.60	95.40	0	24	24	0.00	0.14	–1.00
OV32	1.12	98.88	5.70	94.30	0.18	99.82	156	175	331	0.47	0.02	0.95
OV33	60.75	39.25	42.33	57.67	28.09	71.91	27	107	134	0.20	0.44	–0.51
OV34	75.78	24.22	96.34	3.66	91.43	8.57	0	6	6	0.00	0.88	–1.00
OV35	33.42	66.58	42.21	57.79	32.00	68.00	2	144	146	0.01	0.36	–0.95
OV36	25.34	74.66	31.51	68.49	21.07	78.93	0	944	944	0.00	0.26	–1.00
OV37	39.58	60.42	52.64	47.36	35.96	64.04	4	21	25	0.16	0.43	–0.59
WK02	39.72	60.28	57.66	42.34	40.26	59.74	0	188	188	0.00	0.46	–1.00
Overall	**27.78**	**72.22**	**29.46**	**70.54**	**17.22**	**82.78**	**11.04**	**88.96**	**72278**	**0.11**	**0.25**	**–0.45**

	Southern Free State summer											
	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FS01	97.16	2.84	91.25	8.75	91.37	8.63	4	0	**4**	1.00	0.93	**1.00**
FS02	99.56	0.44	97.85	2.15	98.15	1.85	30	5	**35**	0.86	0.99	**–0.83**
FS04	98.87	1.13	99.20	0.80	98.34	1.66	193	0	**193**	1.00	0.99	**1.00**
FS06	99.41	0.59	99.70	0.30	98.70	1.30	534	0	**534**	1.00	0.99	**1.00**
FS07	99.42	0.58	98.15	1.85	97.56	2.44	60	2	**62**	0.97	0.98	**–0.34**
FS08	98.24	1.76	97.11	2.89	97.11	2.89	62	0	**62**	1.00	0.97	**1.00**
FS09	99.62	0.38	98.63	1.37	98.10	1.90	47	16	**63**	0.75	0.99	**–0.93**
FS11	98.85	1.15	97.04	2.96	97.93	2.07	3	0	**3**	1.00	0.98	**1.00**
FS12	98.74	1.26	96.37	3.63	96.15	3.85	133	0	**133**	1.00	0.97	**1.00**
FS13	98.88	1.12	99.61	0.39	99.10	0.90	11	0	**11**	1.00	0.99	**1.00**
FS14	99.67	0.33	99.94	0.06	98.94	1.06	2	0	**2**	1.00	1.00	**1.00**
FS15	99.77	0.23	99.07	0.93	99.33	0.67	2	0	**2**	1.00	0.99	**1.00**
FS17	95.39	4.61	94.90	5.10	94.62	5.38	14	0	**14**	1.00	0.95	**1.00**
FS18	98.00	2.00	95.81	4.19	96.06	3.94	7	0	**7**	1.00	0.97	**1.00**
FS19	75.56	24.44	82.15	17.85	73.15	26.85	1	0	**1**	1.00	0.77	**1.00**
FS20	75.16	24.84	81.32	18.68	72.95	27.05	1	0	**1**	1.00	0.76	**1.00**
FS21	75.97	24.03	86.48	13.52	75.96	24.04	31	0	**31**	1.00	0.79	**1.00**
FS22	87.84	12.16	84.26	15.74	82.54	17.46	2	0	**2**	1.00	0.85	**1.00**
FS23	97.59	2.41	94.97	5.03	94.75	5.25	48	3	**51**	0.94	0.96	**–0.17**
FS24	99.74	0.26	96.72	3.28	97.63	2.37	4	0	**4**	1.00	0.98	**1.00**
FS25	99.64	0.36	97.11	2.89	97.97	2.03	21	0	**21**	1.00	0.98	**1.00**
FS27	99.40	0.60	96.48	3.52	96.88	3.12	8	0	**8**	1.00	0.98	**1.00**
FS30	73.08	26.92	78.54	21.46	71.45	28.55	11	0	**11**	1.00	0.74	**1.00**
FS31	96.18	3.82	92.09	7.91	89.74	10.26	63	0	**63**	1.00	0.93	**1.00**
FS35	78.52	21.48	81.32	18.68	72.71	27.29	2	0	**2**	1.00	0.78	**1.00**
FS39	95.03	4.97	66.94	33.06	67.57	32.43	8	0	**8**	1.00	0.77	**1.00**
FS40	98.71	1.29	93.62	6.38	92.84	7.16	4	0	**4**	1.00	0.95	**1.00**
FS42	98.83	1.17	76.31	23.69	84.84	15.16	16	2	**18**	0.89	0.87	**0.10**
FS47	71.93	28.07	79.70	20.30	68.89	31.11	3	0	**3**	1.00	0.74	**1.00**
FS48	89.08	10.92	87.94	12.06	83.72	16.28	1	0	**1**	1.00	0.87	**1.00**
FS51	96.58	3.42	93.85	6.15	93.68	6.32	45	6	**51**	0.88	0.95	**–0.41**
FS52	82.35	17.65	78.90	21.10	74.01	25.99	2	0	**2**	1.00	0.78	**1.00**
FS55	97.87	2.13	95.00	5.00	95.22	4.78	14	0	**14**	1.00	0.96	**1.00**
FS56	96.77	3.23	87.57	12.43	87.10	12.90	22	2	**24**	0.92	0.90	**0.07**
FS58	93.94	6.06	87.88	12.12	85.35	14.65	5	2	**7**	0.71	0.89	**–0.53**
FS60	96.29	3.71	82.17	17.83	81.04	18.96	36	0	**36**	1.00	0.87	**1.00**
FS62	96.72	3.28	94.66	5.34	94.76	5.24	3	0	**3**	1.00	0.95	**1.00**
FS67	90.53	9.47	93.55	6.45	86.80	13.20	0	4	**4**	0.00	0.90	**–1.00**
FS69	85.08	14.92	88.28	11.72	83.17	16.83	2	0	**2**	1.00	0.86	**1.00**
FS76	95.83	4.17	94.00	6.00	93.03	6.97	4	0	**4**	1.00	0.94	**1.00**
FS77	87.07	12.93	87.49	12.51	87.33	12.67	5	0	**5**	1.00	0.87	**1.00**
FS82	99.57	0.43	96.80	3.20	97.84	2.16	20	0	**20**	1.00	0.98	**1.00**
FS90	96.98	3.02	94.01	5.99	94.74	5.26	3	0	**3**	1.00	0.95	**1.00**
FS91	68.13	31.87	73.17	26.83	66.78	33.22	11	20	**31**	0.35	0.69	**–0.61**
FS93	99.02	0.98	99.55	0.45	99.16	0.84	153	0	**153**	1.00	0.99	**1.00**
FS94	98.97	1.03	93.91	6.09	94.79	5.21	2	2	**4**	0.50	0.96	**–0.92**
FS95	94.52	5.48	91.65	8.35	92.63	7.37	68	0	**68**	1.00	0.93	**1.00**
FS96	75.19	24.81	82.31	17.69	71.89	28.11	2	0	**2**	1.00	0.76	**1.00**
FS98	99.70	0.30	99.72	0.28	99.03	0.97	15	0	**15**	1.00	0.99	**1.00**
FS100	98.74	1.26	99.05	0.95	98.13	1.87	606	0	**606**	1.00	0.99	**1.00**
FS101	96.78	3.22	90.18	9.82	90.20	9.80	61	43	**104**	0.59	0.92	**–0.79**
FS102	99.61	0.39	97.91	2.09	98.40	1.60	36	0	**36**	1.00	0.99	**1.00**
FS105	99.42	0.58	98.72	1.28	98.66	1.34	200	0	**200**	1.00	0.99	**1.00**
FS109	92.81	7.19	85.83	14.17	85.85	14.15	0	16	**16**	0.00	0.88	**–1.00**
FS115	78.03	21.97	81.98	18.02	72.99	27.01	10	0	**10**	1.00	0.78	**1.00**
FS118	99.52	0.48	99.85	0.15	99.13	0.87	658	0	**658**	1.00	0.99	**1.00**
FS121	73.52	26.48	80.43	19.57	67.81	32.19	0	2	**2**	0.00	0.74	**–1.00**
FS123	97.57	2.43	95.14	4.86	94.37	5.63	16	0	**16**	1.00	0.96	**1.00**

FS124	99.60	0.40	97.84	2.16	98.32	1.68	24	0	24	1.00	0.99	1.00
Overall	**92.79**	**7.21**	**91.03**	**8.97**	**89.03**	**10.97**	**96.40**	**3.60**	**3474**	**0.96**	**0.91**	**0.45**

Southern Free State winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FS02	99.56	0.44	97.85	2.15	98.15	1.85	92	8	100	0.92	0.99	–0.71
FS03	99.43	0.57	98.58	1.42	98.42	1.58	0	93	93	0.00	0.99	–1.00
FS04	98.87	1.13	99.20	0.80	98.34	1.66	486	0	486	1.00	0.99	1.00
FS05	99.83	0.17	99.82	0.18	99.28	0.72	23	0	23	1.00	1.00	1.00
FS06	99.41	0.59	99.70	0.30	98.70	1.30	794	281	1075	0.74	0.99	–0.96
FS07	99.42	0.58	98.15	1.85	97.56	2.44	377	740	1117	0.34	0.98	–0.98
FS08	98.24	1.76	97.11	2.89	97.11	2.89	26	0	26	1.00	0.97	1.00
FS09	99.62	0.38	98.63	1.37	98.10	1.90	26	2	28	0.93	0.99	–0.72
FS10	97.87	2.13	94.27	5.73	94.97	5.03	2	0	2	1.00	0.96	1.00
FS11	98.85	1.15	97.04	2.96	97.93	2.07	4	0	4	1.00	0.98	1.00
FS12	98.74	1.26	96.37	3.63	96.15	3.85	663	71	734	0.90	0.97	–0.56
FS13	98.88	1.12	99.61	0.39	99.10	0.90	43	0	43	1.00	0.99	1.00
FS14	99.67	0.33	99.94	0.06	98.94	1.06	28	3	31	0.90	1.00	–0.91
FS15	99.77	0.23	99.07	0.93	99.33	0.67	4	0	4	1.00	0.99	1.00
FS16	92.64	7.36	92.42	7.58	89.97	10.03	0	11	11	0.00	0.92	–1.00
FS17	95.39	4.61	94.90	5.10	94.62	5.38	33	0	33	1.00	0.95	1.00
FS18	98.00	2.00	95.81	4.19	96.06	3.94	61	20	81	0.75	0.97	–0.81
FS19	75.56	24.44	82.15	17.85	73.15	26.85	3	0	3	1.00	0.77	1.00
FS23	97.59	2.41	94.97	5.03	94.75	5.25	441	680	1121	0.39	0.96	–0.94
FS24	99.74	0.26	96.72	3.28	97.63	2.37	17	3	20	0.85	0.98	–0.80
FS25	99.64	0.36	97.11	2.89	97.97	2.03	9	2	11	0.82	0.98	–0.85
FS27	99.40	0.60	96.48	3.52	96.88	3.12	98	175	273	0.36	0.98	–0.97
FS31	96.18	3.82	92.09	7.91	89.74	10.26	0	77	77	0.00	0.93	–1.00
FS32	99.17	0.83	95.02	4.98	95.53	4.47	3	0	3	1.00	0.97	1.00
FS35	78.52	21.48	81.32	18.68	72.71	27.29	18	203	221	0.08	0.78	–0.95
FS42	98.83	1.17	76.31	23.69	84.84	15.16	4	43	47	0.09	0.87	–0.97
FS46	43.30	56.70	51.33	48.67	42.21	57.79	0	6	6	0.00	0.46	–1.00
FS47	71.93	28.07	79.70	20.30	68.89	31.11	0	11	11	0.00	0.74	–1.00
FS51	96.58	3.42	93.85	6.15	93.68	6.32	65	13	78	0.83	0.95	–0.56
FS54	83.40	16.60	82.30	17.70	72.49	27.51	2	0	2	1.00	0.79	1.00
FS56	96.77	3.23	87.57	12.43	87.10	12.90	2	0	2	1.00	0.90	1.00
FS60	96.29	3.71	82.17	17.83	81.04	18.96	775	615	1390	0.56	0.87	–0.67
FS62	96.72	3.28	94.66	5.34	94.76	5.24	1	0	1	1.00	0.95	1.00
FS69	85.08	14.92	88.28	11.72	83.17	16.83	0	4	4	0.00	0.86	–1.00
FS73	65.56	34.44	72.03	27.97	60.96	39.04	2	0	2	1.00	0.66	1.00
FS76	95.83	4.17	94.00	6.00	93.03	6.97	1	4	5	0.20	0.94	–0.97
FS77	87.07	12.93	87.49	12.51	87.33	12.67	0	8	8	0.00	0.87	–1.00
FS86	68.11	31.89	72.43	27.57	64.93	35.07	1	0	1	1.00	0.68	1.00
FS91	68.13	31.87	73.17	26.83	66.78	33.22	48	0	48	1.00	0.69	1.00
FS93	99.02	0.98	99.55	0.45	99.16	0.84	4	0	4	1.00	0.99	1.00
FS98	99.70	0.30	99.72	0.28	99.03	0.97	6	0	6	1.00	0.99	1.00
FS99	47.83	52.17	50.53	49.47	41.88	58.12	0	206	206	0.00	0.47	–1.00
FS100	98.74	1.26	99.05	0.95	98.13	1.87	381	0	381	1.00	0.99	1.00
FS101	96.78	3.22	90.18	9.82	90.20	9.80	12	278	290	0.04	0.92	–0.99
FS102	99.61	0.39	97.91	2.09	98.40	1.60	2	14	16	0.13	0.99	–1.00
FS105	99.42	0.58	98.72	1.28	98.66	1.34	16	0	16	1.00	0.99	1.00
FS109	92.81	7.19	85.83	14.17	85.85	14.15	4	7	11	0.36	0.88	–0.86
FS112	71.42	28.58	78.01	21.99	70.06	29.94	0	13	13	0.00	0.73	–1.00
FS118	99.52	0.48	99.85	0.15	99.13	0.87	1937	613	2550	0.76	0.99	–0.97
FS123	97.57	2.43	95.14	4.86	94.37	5.63	112	267	379	0.30	0.96	–0.96
FS124	99.60	0.40	97.84	2.16	98.32	1.68	50	18	68	0.74	0.99	–0.92
Overall	**91.68**	**8.32**	**90.62**	**9.38**	**88.70**	**11.30**	**59.79**	**40.21**	**11165**	**0.60**	**0.90**	**–0.73**

Southern KwaZulu-Natal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KG02	80.90	19.10	67.56	32.44	66.51	33.49	4	0	4	1.00	0.72	1.00
KG03	75.42	24.58	72.67	27.33	59.88	40.12	29	13	42	0.69	0.69	–0.01
KG04	74.49	25.51	82.50	17.50	62.77	37.23	10	3	13	0.77	0.73	0.10
KG05	64.23	35.77	69.75	30.25	55.16	44.84	2	0	2	1.00	0.63	1.00
KG07	70.43	29.57	83.46	16.54	67.07	32.93	11	4	15	0.73	0.74	–0.01
KG08	84.60	15.40	81.40	18.60	73.09	26.91	126	165	291	0.43	0.80	–0.67
KG09	61.23	38.77	62.12	37.88	50.34	49.66	36	9	45	0.80	0.58	0.49
KM01	71.51	28.49	66.40	33.60	57.66	42.34	27	0	27	1.00	0.65	1.00
KM02	64.16	35.84	57.70	42.30	57.78	42.22	16	25	41	0.39	0.60	–0.40
KM03	56.99	43.01	60.07	39.93	53.77	46.23	3	3	6	0.50	0.57	–0.14
KM04	86.92	13.08	67.99	32.01	77.05	22.95	3	2	5	0.60	0.77	–0.39
KM05	55.31	44.69	50.98	49.02	52.13	47.87	16	4	20	0.80	0.53	0.56
KM06	60.68	39.32	51.65	48.35	53.78	46.22	12	5	17	0.71	0.55	0.32
KM07	89.76	10.24	75.12	24.88	87.78	12.22	23	0	23	1.00	0.84	1.00
KM08	30.07	69.93	24.92	75.08	24.76	75.24	4	12	16	0.25	0.27	–0.04
KU01	66.95	33.05	66.23	33.77	62.61	37.39	11	2	13	0.85	0.65	0.49
KU02	78.07	21.93	74.09	25.91	69.83	30.17	9	0	9	1.00	0.74	1.00
Overall	68.19	31.81	64.93	35.07	60.33	39.67	58.06	41.94	589	0.58	0.64	–0.13

Southern KwaZulu-Natal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KC01	66.24	33.76	48.49	51.51	57.89	42.11	2	2	4	0.50	0.58	–0.15
KG02	80.90	19.10	67.56	32.44	66.51	33.49	0	9	9	0.00	0.72	–1.00
KG03	75.42	24.58	72.67	27.33	59.88	40.12	6	43	49	0.12	0.69	–0.88
KG04	74.49	25.51	82.50	17.50	62.77	37.23	2	0	2	1.00	0.73	1.00
KG05	64.23	35.77	69.75	30.25	55.16	44.84	30	0	30	1.00	0.63	1.00
KG07	70.43	29.57	83.46	16.54	67.07	32.93	0	124	124	0.00	0.74	–1.00
KG08	84.60	15.40	81.40	18.60	73.09	26.91	0	3	3	0.00	0.80	–1.00
KG09	61.23	38.77	62.12	37.88	50.34	49.66	53	30	83	0.64	0.58	0.12
KM01	71.51	28.49	66.40	33.60	57.66	42.34	50	7	57	0.88	0.65	0.58
KM02	64.16	35.84	57.70	42.30	57.78	42.22	0	16	16	0.00	0.60	–1.00
KM03	56.99	43.01	60.07	39.93	53.77	46.23	2	7	9	0.22	0.57	–0.64
KM04	86.92	13.08	67.99	32.01	77.05	22.95	0	6	6	0.00	0.77	–1.00
KM05	55.31	44.69	50.98	49.02	52.13	47.87	2	2	4	0.50	0.53	–0.06
KM06	60.68	39.32	51.65	48.35	53.78	46.22	8	17	25	0.32	0.55	–0.45
KM07	89.76	10.24	75.12	24.88	87.78	12.22	0	5	5	0.00	0.84	–1.00
KM08	30.07	69.93	24.92	75.08	24.76	75.24	0	7	7	0.00	0.27	–1.00
KU01	66.95	33.05	66.23	33.77	62.61	37.39	7	15	22	0.32	0.65	–0.60
KU02	78.07	21.93	74.09	25.91	69.83	30.17	6	12	18	0.33	0.74	–0.70
Overall	68.12	31.88	64.33	35.67	60.24	39.76	35.52	64.48	473	0.36	0.64	–0.53

Steenkampsberg summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MS01	90.35	9.65	91.55	8.45	90.87	9.13	4	0	4	1.00	0.91	1.00
MS02	87.69	12.31	93.88	6.12	93.06	6.94	7	2	9	0.78	0.92	–0.51
MS04	80.25	19.75	85.99	14.01	80.09	19.91	2	2	4	0.50	0.82	–0.64
MS05	90.34	9.66	84.28	15.72	83.98	16.02	10	4	14	0.71	0.86	–0.43
MS06	82.19	17.81	84.64	15.36	83.39	16.61	24	4	28	0.86	0.83	0.09
MS07	93.50	6.50	92.62	7.38	90.89	9.11	4	3	7	0.57	0.92	–0.80
MS08	90.48	9.52	92.87	7.13	88.94	11.06	13	4	17	0.76	0.91	–0.50
MS13	74.62	25.38	78.82	21.18	78.20	21.80	2	0	2	1.00	0.77	1.00
Overall	85.68	14.32	87.69	12.31	85.82	14.18	77.65	22.35	85	0.78	0.86	–0.29

Steenkampsberg winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MS04	80.25	19.75	85.99	14.01	80.09	19.91	0	2	2	0.00	0.82	–1.00
MS05	90.34	9.66	84.28	15.72	83.98	16.02	2	1	3	0.67	0.86	–0.51
MS09	84.09	15.91	88.12	11.88	80.83	19.17	1	0	1	1.00	0.84	1.00
Overall	84.70	15.30	86.13	13.87	81.57	18.43	50.00	50.00	6	0.50	0.84	–0.68

Swartland summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
SW01	6.04	93.96	2.57	97.43	15.05	84.95	11	274	285	0.04	0.08	–0.36
SW02	5.56	94.44	6.02	93.98	14.10	85.90	30	19	49	0.61	0.09	0.89
SW03	18.27	81.73	21.52	78.48	30.87	69.13	0	262	262	0.00	0.24	–1.00
SW04	13.97	86.03	8.48	91.52	19.90	80.10	1	61	62	0.02	0.14	–0.82
SW05	1.24	98.76	1.27	98.73	9.91	90.09	3	127	130	0.02	0.04	–0.29
SW06	8.00	92.00	10.14	89.86	21.97	78.03	14	418	432	0.03	0.13	–0.64
SW07	8.15	91.85	10.98	89.02	17.59	82.41	5	404	409	0.01	0.12	–0.84
SW08	19.31	80.69	23.18	76.82	36.07	63.93	20	145	165	0.12	0.26	–0.44
SW09	1.94	98.06	2.55	97.45	11.15	88.85	18	401	419	0.04	0.05	–0.10
SW10	11.12	88.88	14.96	85.04	35.51	64.49	0	120	120	0.00	0.21	–1.00
SW11	19.79	80.21	22.57	77.43	15.37	84.63	5	59	64	0.08	0.19	–0.48
SW12	34.12	65.88	27.07	72.93	38.93	61.07	0	111	111	0.00	0.33	–1.00
SW13	18.03	81.97	13.47	86.53	30.38	69.62	5	103	108	0.05	0.21	–0.69
SW14	19.64	80.36	15.14	84.86	23.87	76.13	20	197	217	0.09	0.20	–0.41
SW15	45.23	54.77	25.25	74.70	14.13	85.87	13	335	348	0.04	0.28	–0.82
SW16	1.48	98.52	5.28	94.72	13.99	86.01	0	45	45	0.00	0.07	–1.00
Overall	14.36	85.64	13.17	86.83	22.23	77.77	4.49	95.51	3226	0.04	0.17	–0.62

Swartland winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
SW01	6.04	93.96	2.57	97.43	15.05	84.95	1	1199	1200	0.00	0.08	–0.98
SW02	5.56	94.44	6.02	93.98	14.10	85.90	0	16	16	0.00	0.09	–1.00
SW03	18.27	81.73	21.52	78.48	30.87	69.13	78	1108	1186	0.07	0.24	–0.63
SW04	13.97	86.03	8.48	91.52	19.90	80.10	2	1457	1459	0.00	0.14	–0.98
SW05	1.24	98.76	1.27	98.73	9.91	90.09	2	1109	1111	0.00	0.04	–0.92
SW06	8.00	92.00	10.14	89.86	21.97	78.03	2	259	261	0.01	0.13	–0.90
SW07	8.15	91.85	10.98	89.02	17.59	82.41	0	485	485	0.00	0.12	–1.00
SW08	19.31	80.69	23.18	76.82	36.07	63.93	54	223	277	0.19	0.26	–0.19
SW09	1.94	98.06	2.55	97.45	11.15	88.85	24	497	521	0.05	0.05	–0.06
SW10	11.12	88.88	14.96	85.04	35.51	64.49	0	258	258	0.00	0.21	–1.00
SW11	19.79	80.21	22.57	77.43	15.37	84.63	17	110	127	0.13	0.19	–0.21
SW12	34.12	65.88	27.07	72.93	38.93	61.07	3	439	442	0.01	0.33	–0.97
SW13	18.03	81.97	13.47	86.53	30.38	69.62	0	807	807	0.00	0.21	–1.00
SW14	19.64	80.36	15.14	84.86	23.87	76.13	0	498	498	0.00	0.20	–1.00
SW15	45.23	54.77	25.25	74.70	14.13	85.87	24	238	262	0.09	0.28	–0.59
SW16	1.48	98.52	5.28	94.72	13.99	86.01	0	12	12	0.00	0.07	–1.00
Overall	14.36	85.64	13.17	86.83	22.23	77.77	2.32	97.68	8922	0.02	0.17	–0.79

Wakkerstroom summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MW01	76.70	23.30	51.24	48.76	59.92	40.08	2	0	**2**	1.00	0.63	**1.00**
MW03	90.38	9.62	92.84	7.16	88.01	11.99	69	8	**77**	0.90	0.90	**–0.04**
MW04	90.05	9.95	91.83	8.17	87.32	12.68	4	0	**4**	1.00	0.90	**1.00**
MW06	72.17	27.83	85.12	14.88	70.39	29.61	4	0	**4**	1.00	0.76	**1.00**
MW07	77.81	22.19	88.44	11.56	80.17	19.83	7	4	**11**	0.64	0.82	**–0.45**
MW08	86.45	13.55	81.53	18.47	81.53	18.47	2	0	**2**	1.00	0.83	**1.00**
MW09	82.99	17.01	86.58	13.42	83.48	16.52	2	0	**2**	1.00	0.84	**1.00**
Overall	**82.85**	**17.15**	**83.15**	**16.85**	**79.50**	**20.50**	**88.24**	**11.76**	**102**	**0.88**	**0.82**	**0.25**

Wakkerstroom winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MW01	76.70	23.30	51.24	48.76	59.92	40.08	3	9	**12**	0.25	0.63	**–0.67**
MW03	90.38	9.62	92.84	7.16	88.01	11.99	62	54	**116**	0.53	0.90	**–0.78**
MW04	90.05	9.95	91.83	8.17	87.32	12.68	0	6	**6**	0.00	0.90	**–1.00**
MW06	72.17	27.83	85.12	14.88	70.39	29.61	0	6	**6**	0.00	0.76	**–1.00**
MW07	77.81	22.19	88.44	11.56	80.17	19.83	2	4	**6**	0.33	0.82	**–0.80**
MW08	86.45	13.55	81.53	18.47	81.53	18.47	2	0	**2**	1.00	0.83	**1.00**
MW09	82.99	17.01	86.58	13.42	83.48	16.52	0	14	**14**	0.00	0.84	**–1.00**
MW10	83.03	16.97	92.86	7.14	85.41	14.59	0	23	**23**	0.00	0.87	**–1.00**
Overall	**82.87**	**17.13**	**84.12**	**15.88**	**80.09**	**19.91**	**37.30**	**62.70**	**185**	**0.37**	**0.82**	**–0.77**

Western KwaZulu-Natal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD06	92.86	7.14	84.75	15.25	77.90	22.10	14	0	**14**	1.00	0.85	**1.00**
KD11	61.95	38.05	14.85	85.15	47.38	52.62	21	0	**21**	1.00	0.41	**1.00**
KE01	82.04	17.96	70.85	29.15	74.78	25.22	4	2	**6**	0.67	0.76	**–0.22**
KE03	59.85	40.15	62.10	37.90	48.91	51.09	0	3	**3**	0.00	0.57	**–1.00**
KL01	87.32	12.68	88.82	11.18	82.75	17.25	44	3	**47**	0.94	0.86	**0.40**
KL02	67.39	32.61	75.22	24.78	57.50	42.50	4	0	**4**	1.00	0.67	**1.00**
KL03	56.62	43.38	68.84	31.16	52.48	47.52	0	2	**2**	0.00	0.59	**–1.00**
Overall	**72.87**	**27.13**	**69.00**	**31.00**	**64.06**	**35.94**	**89.69**	**10.31**	**97**	**0.90**	**0.69**	**0.60**

Western KwaZulu-Natal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. BCs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD06	92.86	7.14	84.75	15.25	77.90	22.10	5	12	**17**	0.29	0.85	**–0.86**
KD11	61.95	38.05	14.85	85.15	47.38	52.62	6	2	**8**	0.75	0.41	**0.62**
KE01	82.04	17.96	70.85	29.15	74.78	25.22	0	2	**2**	0.00	0.76	**–1.00**
KE04	61.10	38.90	72.15	27.85	60.88	39.12	0	2	**2**	0.00	0.65	**–1.00**
KL01	87.32	12.68	88.82	11.18	82.75	17.25	39	104	**143**	0.27	0.86	**–0.89**
KL02	67.39	32.61	75.22	24.78	57.50	42.50	16	20	**36**	0.44	0.67	**–0.43**
KL03	56.62	43.38	68.84	31.16	52.48	47.52	2	3	**5**	0.40	0.59	**–0.37**
KL07	91.39	8.61	93.26	6.74	70.57	29.43	3	8	**11**	0.27	0.85	**–0.88**
KL08	92.73	7.27	98.69	1.31	84.51	15.49	0	20	**20**	0.00	0.92	**–1.00**
Overall	**75.84**	**24.16**	**74.02**	**25.98**	**66.95**	**33.05**	**29.10**	**70.90**	**244**	**0.29**	**0.72**	**–0.73**

Table A2.3: Four sets of unequal weights used to produce the national population indices for the Blue Crane. (The fifth set used equal weighting, i.e. a weight of 0.08 for each precinct.) The area of a precinct was defined as that of all the quarter-degree grid cells the routes of that precinct entered. This was also the area for which reporting rates (RR, defined as the percentage of atlas checklists from a precinct which reported Blue Cranes) were extracted. Reporting rates from SABAP1 were used (Harrison et al. 1997). For the "Area*Griffioen RR" weightings, the conversion proposed by Griffioen (2001) was applied to the reporting rates (see text) before multiplying them by the precinct areas.

	Area			RR			Area*RR			Area*Griffioen RR		
		Weights			Weights			Weights			Weights	
Precinct	km^2	Summer	Winter	%	Summer	Winter	km^2*%	Summer	Winter	$km^2*(-ln(1-RR))$	Summer	Winter
E Cape Coastal	6000.30	0.02	0.02	8.46	0.03	0.03	50739.76	0.01	0.01	530.14	0.01	0.01
E Cape Karoo	33402.90	0.11	0.11	30.56	0.10	0.11	1020759.52	0.14	0.15	12181.80	0.14	0.15
Eastern Karoo	31929.79	0.11	0.10	41.48	0.13	0.14	1324598.28	0.18	0.19	17110.61	0.20	0.21
Little Karoo	16713.02	0.06	0.05	7.68	0.02	0.03	128384.27	0.02	0.02	1335.83	0.02	0.02
NE Eastern Cape	24196.92	0.08	0.08	21.11	0.07	0.07	510769.23	0.07	0.07	5737.12	0.07	0.07
NE Free State	25538.33	0.09	0.08	34.93	0.11	0.12	892083.32	0.12	0.13	10974.44	0.13	0.13
Northern KZN	17474.62	0.06		33.98	0.11		593715.83	0.08		7254.59	0.08	
NW Free State	37650.92		0.12	6.85		0.02	257853.08		0.04	2671.08		0.03
Overberg	17706.28	0.06	0.06	41.72	0.13	0.14	738634.67	0.10	0.11	9558.60	0.11	0.12
S Free State	69379.59	0.24	0.22	14.29	0.05	0.05	991528.25	0.14	0.14	10699.48	0.12	0.13
Southern KZN	15870.03	0.05	0.05	23.68	0.07	0.08	375841.94	0.05	0.05	4289.16	0.05	0.05
Swartland	12307.75	0.04	0.04	6.78	0.02	0.02	83436.11	0.01	0.01	863.99	0.01	0.01
Wakkerstroom	7784.46	0.03	0.03	26.90	0.09	0.09	209421.22	0.03	0.03	2439.46	0.03	0.03
Western KZN	12190.02	0.04	0.04	24.86	0.08	0.09	303062.99	0.04	0.04	3484.37	0.04	0.04

Table A2.4: National population index values calculated for the Blue Crane using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weights given in Table A2.3 and summing the results for each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1994	0.32	0.31	0.27	0.28	0.27
1995	0.40	0.38	0.37	0.36	0.36
1996	0.43	0.41	0.42	0.40	0.39
1997	0.50	0.50	0.48	0.49	0.49
1998	0.54	0.52	0.52	0.52	0.52
1999	0.53	0.49	0.52	0.49	0.49
2000	0.62	0.61	0.62	0.60	0.60
2001	0.68	0.63	0.66	0.62	0.62
2002	0.73	0.70	0.71	0.70	0.70
2003	0.90	0.96	0.89	0.94	0.94
2004	0.74	0.72	0.66	0.65	0.65
2005	0.95	0.78	0.78	0.69	0.69
2006	0.94	0.88	0.86	0.81	0.80
2007	0.89	0.88	0.86	0.85	0.85
2008	0.91	0.87	0.81	0.80	0.80
2009	1.30	1.26	1.07	1.05	1.04
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1993	0.39	0.42	0.45	0.47	0.47
1994	0.48	0.49	0.57	0.57	0.57
1995	0.49	0.50	0.58	0.58	0.58
1996	0.47	0.48	0.56	0.56	0.57
1997	0.55	0.59	0.66	0.70	0.71
1998	0.61	0.57	0.66	0.67	0.68
1999	0.53	0.51	0.62	0.59	0.61
2000	0.69	0.68	0.75	0.75	0.76
2001	0.64	0.71	0.73	0.80	0.81
2002	0.73	0.70	0.74	0.75	0.76
2003	0.84	0.84	0.86	0.87	0.87
2004	0.95	1.03	0.99	1.09	1.10
2005	1.06	0.94	1.05	0.97	0.98
2006	0.97	0.84	0.91	0.90	0.91
2007	0.96	0.85	0.81	0.75	0.76
2008	1.11	1.05	1.13	1.12	1.14
2009	1.01	0.88	0.94	0.85	0.86
2010	1.00	1.00	1.00	1.00	1.00

Chapter 5

Denham's Bustard *Neotis denhami stanleyi*: a southern African subspecies at risk?

It is not unusual when motoring through this area, to see solitary specimens of this magnificent bird striding through roadside cultivated lands or amongst the low "fynbos" of the coastal flats.
It is an arresting sight to see this unusually large bird winging its way along the horizon with powerful sweeping wing beats.
Like all bustards the Stanley bustard is excessively shy and difficult to approach closely.

~ C Uys, 1963

Abstract

The local subspecies of Denham's Bustard *Neotis denhami stanleyi* is an isolated endemic subspecies classified as Vulnerable. Habitat destruction and modification have affected much of its natural habitat in the Grassland and Fynbos biomes. This study assessed the status of the population using data from two long-term public participation bird monitoring projects. Population trends produced using Coordinated Avifaunal Roadcounts (CAR) project data for 1993–2010 suggested that Denham's Bustard abundance may have increased in the Overberg region of the Western Cape and along the southern coastal belt of the Eastern Cape, but decreased in southern KwaZulu-Natal. Comparison of data from the first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992, and SABAP2, 2007–) yielded similar results and suggested that the population decreased overall. CAR habitat use data showed that Denham's Bustards make extensive use of transformed habitats in some precincts, especially those in the Fynbos, karoo and Albany Thicket, and more so in winter than in summer. National population indices produced using CAR and SABAP data showed that the population increased slightly or remained stable, but the species population was relatively poorly covered by CAR. We recommend that it remain classified as Vulnerable and is monitored closely, especially in light of the threat posed by the powerline collisions.

Introduction

The Denham's Bustard *Neotis denhami* has a wide range through sub-Saharan Africa, stretching from South Africa in the south to west Africa, Uganda and Ethiopia in the north (Collar 1996). There are three subspecies: *denhami*, *jacksoni* and *stanleyi*; the latter is endemic to South Africa and Swaziland and is isolated from the rest of the population (Allan 1997). This subspecies occurs along the southern coastal belt of the Western and Eastern Cape provinces, and in the primarily grassland habitats in KwaZulu-Natal, Mpumalanga, Limpopo and the north-eastern Free State (Figure 1a).

Like most of the world's 25 bustard species, the Denham's Bustard is poorly studied and comparatively little is known of its habits, movements and population status. However, researchers generally agree that the species is declining in parts of its range (Collar 1996) and in 2004 it was listed as Near Threatened on the IUCN Red List (BirdLife International 2012). In South Africa *stanleyi* is classified as Vulnerable

(Barnes 2000), and is believed to have declined in numbers and range in much of the country (Allan 2005). The principal reasons for the decline are thought to be habitat loss and human disturbance. Denham's Bustards are shy birds which occur mostly in open grassland and low scrub habitats, although they are also found in sparse woodland habitats (Figure 1a) (Allan 2005). Conversion of much of their natural habitat to cultivated land, dense human settlements and forestry plantations, mainly in the east of the country, has greatly reduced the amount of suitable habitat (Herholdt 1988, Tarboton 1989, Allan 1997), and the subspecies' distribution is now patchy and bird atlas reporting rates are lower than 20% over much of its range (Figure 1b). However, in the Fynbos biome Denham's Bustards appear to have adapted to modern agriculture to some extent, and they are regularly seen in pastures and crop fields (Allan 2003). Their distribution is less patchy and reporting rates are on average higher in the Western Cape (Figure 1b). The Coordinated Avifaunal Roadcounts (CAR) project began monitoring the species in 1993 in the Western Cape, and by 1998 had expanded to cover much of its range (Chapter 1, Young et al. 2003). The first Southern African Bird Atlas Project (SABAP1) collected much valuable data on the species between 1987 and 1992 (Harrison et al. 1997), and SABAP2 began accumulating a new data set with which to compare it in 2007 (Chapter 1).

This study aims to use the data from the CAR project, SABAP1 and SABAP2 to determine the current status of the Denham's Bustard in South Africa, using methods developed in an earlier study (Chapter 3). CAR project data are used to assess population trends of the species in as many areas as possible, and to examine habitat use and selection in these areas to gain a better understanding of the needs of and threats to this species. SABAP data are compared numerically to further examine the changes in status of the species between the two data collection periods. Finally, CAR data and SABAP data are combined to produce a national population index for the species.

Methods

CAR project

Data collection

The CAR project was initiated in 1993 in the Overberg region of the Western Cape, and expanded to cover much of the south-eastern half of South Africa over the following eight years (Chapter 1, Young et al. 2003). Volunteers undertook surveys of defined "routes", with a target distance of about 60 km each. The routes, which were primarily through agricultural areas, were surveyed twice a year, once in summer and once in winter. Denham's Bustards observed along the route were counted according to a strict protocol, and relevant variables were collected (Chapter 1). Allan (1993) considered that 1 500 m is the maximum distance at which Denham's Bustards are visible from a road when using binoculars; in many places the distance visible from the road is greater than this. We thus interpret the counts as an index of the number of Denham's Bustards within a transect 3 000 m wide, symmetrically placed on either side of the route. However, CAR observers did not record the distance from the road of each sighting, precluding the application of "distance sampling" (Buckland et al. 1993) to the data; it was therefore not possible to transform the counts into densities. Thus one of the constraints imposed by the data collection protocol is that the results need to be expressed in linear units; the convenient metric is birds per 100 km.

Analysis – population trends

The CAR routes were separated into "precincts" — ecologically distinct areas with similar vegetation and climate characteristics — based on the precincts used in the Mazda CAR report (Young et al. 2003) and by examining vegetation maps (Mucina and Rutherford 2006) of areas surrounding any new routes. The count data for each precinct were analysed separately. Only precincts with sufficient data for a meaningful analysis were used; the estimated total number of birds for entire precinct and period both counted and imputed (see Chapter 3 for precise definition) was greater than 150. Summer and winter surveys were analysed separately.

The Underhill index (Underhill and Prŷs-Jones 1994) was applied to the data (Chapter 3). The resulting annual precinct totals were analysed in the same way as those for the Southern Black Korhaan *Afrotis afra* (Chapter 3).

Analysis – habitat use

Habitat use data collected by CAR project participants were extracted and summarised. Additional precincts were included which did not have sufficient data for the population trend analysis, but did for the habitat selection analysis. Precincts were included if the number of routes on which Denham's Bustards were observed in at least one of the seasons was five or more.

Habitat selection and habitat use were analysed as for the Southern Black Korhaan (Chapter 3), with the following exceptions. Habitat availability was calculated using the 1994 National Land-Cover map (NLC1994) (Thompson 1999) in addition to NLC2000 and NLC2009 (CSIR and ARC 2005, SANBI 2009). The earlier map was included so as to give a more accurate representation of habitat availability for the entire period over which Denham's Bustards were surveyed (1993–2010). Buffer zones formed around each route were 3 000 m wide, because Denham's Bustards up to 1 500 m from the road could have been recorded by CAR observers (Allan 1993).

Southern African Bird Atlas Projects

Data collection

The first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) represent distinct iterations of southern Africa's largest-scale bird monitoring project (Harrison et al. 2008). The protocol used for SABAP1 (1987–1992) is described in Chapter 1 and in Harrison and Underhill (1997), and for SABAP2 (2007–) on the project's website (http://sabap2.adu.org.za/), and a summary is provided in Chapter 1.

SABAP comparison map

We used a visual method, termed a SABAP comparison map, to examine the changes in raw reporting rates for the species from the first atlas project to the second, using all data submitted up until 10 February 2012. A statistic which takes into account the difference in reporting rates and sample sizes of checklists was calculated for each atlas quarter-degree grid cell (QDGC) to evaluate the importance of these changes (Chapter 3).

National population trend index

The status of the Denham's Bustard population as a whole was modelled using the method developed for the Southern Black Korhaan (Chapter 3) and Blue Crane *Anthropoides paradiseus* (Chapter 4). The proportion of the species' range covered by the CAR project, and the importance of this area in terms of the whole population, was assessed.

Results

CAR data

Population trends

Five precincts had sufficient data for population trend analysis: Overberg, Little Karoo, Eastern Cape Coastal, North-eastern Eastern Cape and Southern KwaZulu-Natal (Figure 1 in Chapter 1). By far the largest number of Denham's Bustards was seen in the longest running precinct, Overberg (Table 1). Overall, 8 298 birds were recorded on 88 routes averaging 54.3 km in length. To ensure that the percentage of the overall total imputed in each analysis was less than 25%, the data were adjusted in various ways (Table 2).

During the study period, populations of Denham's Bustards increased in the Eastern Cape Coastal and Overberg precincts, decreased in the Southern KwaZulu-Natal precinct, showed no discernible trend in the North-eastern Eastern Cape and were relatively stable in the Little Karoo (Figure 2; Appendix 3, Table A3.1).

The Eastern Cape Coastal precinct had the largest average population density (11.8 birds/100 km for summer, SD 6.1; 23.1 birds/100 km for winter, SD 7.8), more than double the next most densely populated precincts, Little Karoo and Overberg. This precinct's population increased by between 5% (summer average) and 8% (winter average) per year, although the trend for winter ($R^2 = 0.69$) was stronger than that for summer ($R^2 = 0.27$). For the Overberg the smoothed trend for the summer surveys showed an increase in population until 2007, after which numbers began to decline. However, in 2007 unusually large numbers of birds were seen; if this survey is disregarded the population stabilised at c. 4 birds/100 km in 2001. The average density for winter (12.5 birds/100 km, SD 3.3) was more than triple that for summer (3.9 birds/100 km, SD 2.2), but no trend was apparent in the winter totals. The Southern KwaZulu-Natal population decreased by an average of 1% per year. The winter average (4.3 birds/100 km, SD 1.6) was close to twice the summer average (2.2 birds/100 km, SD 0.9) but the summer trend was stronger ($R^2 = 0.61$ for summer and 0.31 for winter). Count totals for the North-eastern Eastern Cape were variable in both seasons and no trend was apparent; however summer totals (2.3 birds/100 km, SD 1.0) were smaller than winter (3.0 birds/100 km, SD 1.2). Little Karoo totals were variable from year to year for summer counts (5.2 birds/100 km, SD 3.5) but more constant in winter except for the 2003 survey, for which the density was 21.0 birds/100 km; excluding this value the mean was 4.9 birds/100 km (SD 1.9). The summer survey immediately following this survey (2004) recorded an unusually large total for this series. According to the winter surveys, this population was increasing until 2004, after which it stabilised.

Habitat use

The additional precincts included for the habitat selection and use analyses were Eastern Karoo, Eastern Cape Karoo, North-eastern Free State, Northern KwaZulu-Natal, Steenkampsberg and Wakkerstroom (Figure 1 in Chapter 1). Denham's Bustards showed unequivocal preference for natural habitats in the Eastern Karoo and North-eastern Free State precincts (Table 3; Appendix 3, Table A3.2). They preferred transformed habitats in the Little Karoo and Overberg in both summer and winter, and in the Eastern Cape Coastal and Southern KwaZulu-Natal precincts in winter only. In other precincts the signal was more confused. For example, in the Eastern Cape Karoo bustards showed a preference for transformed land in terms of overall numbers of birds and the percentage of each type of land available to them in the whole precinct, but they selected for natural land on the majority of routes.

In summer over 80% of Denham's Bustards observed were in natural veld or at water in all but three precincts: Overberg, Little Karoo and Eastern Cape Coastal (Figure 3a). The most important habitat types for Denham's Bustards in these three precincts were pasture, fallow and stubble (harvested crop fields). The small proportion of birds that were seen in transformed habitats in other precincts in summer tended to be in pastures, fallow land or crop fields.

In winter the proportion of birds seen in natural veld or at water was 80% or greater in only three precincts: Eastern Karoo, North-Eastern Free State and Wakkerstroom (Figure 3b). The most-used transformed habitats were pasture (Eastern Cape precincts, Overberg and Southern KwaZulu-Natal), stubble (Eastern Cape Karoo, KwaZulu-Natal precincts and Wakkerstroom) and fallow land (Eastern Cape Coastal and Western Cape precincts). Crop fields were also an important habitat in the Western Cape precincts.

SABAP comparison map

Overall between the data collection period for SABAP1 and that for SABAP2 reporting rates of Denham's Bustards increased or remained stable in the Western Cape and south-western coastal plain of the Eastern Cape, and decreased or remained stable throughout the rest of the range (Figure 4).

Reporting rates increased in the western part of the Overberg and in the Eastern Cape Coastal precinct (dark blue and dark green QDGCs). They decreased in parts of KwaZulu-Natal (red and orange QDGCs), and did not change significantly in the Little Karoo, Mpumalanga and north-eastern Eastern Cape regions (pale green and yellow QDGCs). However, the majority of QDGCs in the Western Cape (32 of 54) showed increased reporting rates (light or dark green or dark blue), whereas the opposite was true for the remainder of the range (206 of 298 QDGCs were red, orange or yellow). Of the 53 QDGCs in which there was an important decrease in reporting rates, 23 were in KwaZulu-Natal, including two closely clustered groups. The remainder were widely dispersed, but 17 of these were in the Eastern Cape. Reporting rates on the north-eastern KwaZulu-Natal coastal plain, where there was previously an isolated breeding population (Allan 2005), were zero for SABAP2 for 12 of the 14 QDGCs in this area.

National population index

The three sets of weights involving area down-weighted the Eastern Cape Coastal precinct (weights of 0.06–0.07), and those involving reporting rate down-weighted the Little Karoo (0.04; Appendix 3, Table A3.3). The weights for the North-eastern Eastern Cape and Overberg precincts increased in all four sets of unequal weights; North-eastern Eastern Cape was more heavily weighted for the two sets of weights involving both area and reporting rate (0.42 and 0.43, compared to 0.28 for the Overberg). Southern KwaZulu-Natal's weighting remained approximately neutral (i.e. c. 0.20) for all sets of weights.

All five sets of weights yielded similar population indices for the years 2001–10 (summer) and 2000–10 (winter; Figure 5; Appendix 3, Table A3.4). Prior to that the indices not weighted by reporting rate were c. 30% higher for the summer trends, and for winter the values were spread out, with the indices weighted by both area and reporting rate consistently the highest and the equally-weighted index the lowest. Summer indices weighted by both area and reporting rate indicated that the portion of the Denham's Bustard population covered by the CAR project remained approximately stable between 1994 and 2010, although in the years 2001–06 the index was slightly below the 2010 level, and there was a spike up to 160% of the 2010 level in 2007. The equivalent winter indices suggest that the population increased by c. 33% between 1993 and 2010, although there were dips down to c. 50% of the 2010 level in 1998–99, 2002 and 2007. The percentage of the range of the species that was covered by this analysis was c. 32%.

Discussion

CAR data

Population trends

The Denham's Bustard population increased in the most densely populated precinct, Eastern Cape Coastal, by an average of 5–8% per year, but decreased in Southern KwaZulu-Natal, which along with North-eastern Eastern Cape had the lowest average density (Figure 2). The population also increased and then stabilised in c. 2004 in the Overberg and Little Karoo precincts, according to the trends for the seasons in which numbers were more consistent (summer and winter respectively).

Population increases probably occurred as a result of an increase in favourable habitat due to land transformation, because the species showed at least some preference for transformed land in the precincts in which it increased. This increase in suitable habitat probably caused an increase in breeding success, due to increased food supply. Where declines occurred, either prior to or during the study period, this was paradoxically probably also related to land transformation. Transformation of grassland into less suitable habitat such as forestry plantations and maize crop fields would render much of that habitat unavailable to Denham's Bustards. This would have led to a decrease in available breeding territories and food, with a concomitant decline in breeding success. In addition, adult mortality rates probably increased because of powerline collisions, fence entanglement, persecution, hunting and disturbance.

The Overberg results were consistent with Allan's (2003) observation of three to four times as many Denham's Bustards there in winter than in summer, but that numbers are less variable in summer than in winter. Denham's Bustards breed in spring and summer (Allan 2005); the majority of egg-laying takes place in October and November with the latest recorded in December, and incubation is c. 24 days. Thus at the time of the summer CAR counts in the last week of January, breeding females and chicks are mobile, and adult males are no longer displaying. It is likely that adult females with chicks attempt to remain as inconspicuous as possible until their young have fledged, and in the Overberg at least they have been found to prefer natural veld habitats during the breeding season, where they would be less conspicuous than in agricultural landscapes (Allan 2003). These birds are also more conspicuous in groups, which they tend to form when not breeding (Allan 2003). This probably explains to some extent the larger and more variable numbers observed in winter. Seasonal formation of flocks should cause the numbers of birds observed to be more variable in that season, because the chances of encountering any birds are reduced, but when they are encountered more are observed at one sighting.

The increase in densities in winter was observed in all precincts (although the extent of the increase varied). It is thought that this subspecies displays some degree of altitudinal migration (Allan 2003, 2005). Our results suggest that in some areas, such as the Eastern Cape Coastal and Little Karoo precincts, the population either remains the same year-round or a consistent number of birds migrates to these areas in winter, because winter totals were relatively consistent. However, in areas such as the Overberg and Southern KwaZulu-Natal precincts, where winter count totals were variable, birds may leave or migrate to the area in winter depending on conditions there and elsewhere. Allan (2003) suggested that there may be some altitudinal migration down to the Overberg coastal plain in winter, but also mentioned that a small number of birds (described as vagrants) moves into the edges of the Nama Karoo biome adjacent to the Fynbos and Grassland biomes outside the breeding season. This suggests that this species is to some extent nomadic in the non-breeding season. The degree of variation in winter CAR survey totals for the Overberg and Southern KwaZulu-Natal precincts is consistent with a nomadic species that only moves to an area in any numbers if the climatic conditions are favourable. In the winter 2003 survey an unusually large number of bustards, comprised of several flocks of no more than ten birds each, was seen on one route in the Little Karoo precinct. In the same survey an unusually large number of Blue Cranes was recorded. The observers commented that the dams were fuller and vegetation was greener than usual, suggesting that this may have been the reason for the large numbers of birds seen (M Euston-Brown, in litt.). This instance supports the notion that this species is to some extent nomadic when not breeding.

In some precincts numbers of Denham's Bustards recorded by CAR project participants were too variable in one or both seasons to detect any trend in the population. This may mean that the populations were stable, or that the species was too nomadic in some areas and/or seasons for the CAR project to detect trends, although possibly a longer time series might reveal trends. Sightings of seasonally formed nomadic flocks can cause outliers in population count data which have a strong effect on a trend analysis. This was the case in the Little Karoo winter analysis mentioned above. If 2003 is excluded from the analysis, R^2 increases from 0.44 to 0.67, and the trend changes to one that increases over the whole study period. The ability to detect population trends is therefore weakened by seasonal nomadic movements and flocking behaviour.

Seasonal changes in vegetation structure may affect the detectability of Denham's Bustards. This effect would be different in different biomes, however. Allan (2003) found that in the Overberg Denham's Bustards tend to be more conspicuous in winter, because fewer birds utilise natural veld (Fynbos) in winter, and Fynbos consists of short to medium height shrubby vegetation, where Denham's Bustards are less detectable than in pastures and stubble fields (see the following section, however). Vegetation height in this region in late July does not vary substantially from year to year (SDH pers. obs), so this cannot explain the variability in Overberg winter count totals. In the Southern KwaZulu-Natal precinct, however, where the majority of birds were seen in natural veld (Grassland) in both summer and winter (Figure 3), detectability of the birds would in general be higher in winter, but it would vary depending on how much of the vegetation had been burned by the time of the winter surveys (SDH pers. obs). Changes in vegetation structure may therefore be responsible for some of the annual variability in count totals in some precincts, but they are unlikely to be the sole cause.

Habitat use

Allan (2003) reported that in the Overberg Denham's Bustards favour natural veld in summer and select against it in winter. CAR project participants, however, observed a similar and highly significant degree of selection against natural habitats in the Overberg in both summer and winter (Table 3). Allan, though, counted only September to December as "summer" for the analysis of the use of natural veld, and the months in which he reported Denham's Bustards selecting against natural veld were January to August. There is thus no contradiction between the current findings and his, because summer CAR counts took place in the last week of January. He also found that Denham's Bustards favour pastures in winter, crop stubbles when available (mostly summer in the Overberg), and that they avoid ploughed fields and fields with growing crops all year round. Although the lack of detailed habitat availability data precludes an equivalent analysis here, this study's findings agree to some extent with Allan's. Crop stubble was the most-used habitat in summer, as was pasture in the winter. Crop fields and ploughed fields were very little used in summer, but in winter more than 25% of birds observed were in crop fields. (They may still have been selecting against crop fields, however, if this habitat constituted more than 25% of the area surveyed.)

In all but two of the precincts (Eastern Karoo and North-eastern Free State) Denham's Bustards exhibited a greater degree of selection for transformed habitats in winter. This implies that in general they find natural habitats more favourable for breeding and other uses in summer. It is possible that transformed habitats are somewhat more hospitable than natural in winter. In summer rainfall areas (the whole species range except for the Little Karoo and Overberg; Chapter 1) water and food would both tend to be scarcer in winter, and transformed habitats would artificially supplement both of these. The difference in preference shown for transformed habitats in the Little Karoo and Overberg precincts is slight in comparison with the other precincts. This is consistent with the above explanation because the advantages offered by transformed habitats would not be as dependent on season in these areas. These advantages in the Western Cape are probably linked to the greater ease of mobility and possibly to greater food availability in transformed habitats.

The greater degree of selection for transformed habitats in the Little Karoo, Overberg and Eastern Cape Coastal precincts may offer some explanation for the stable or increasing population trends observed in these precincts. Denham's Bustards may have benefitted from land transformation in these areas during the study period, because this transformation represented an improvement in habitat quality for this species. However, this typically would not apply in the Grassland biome, and populations in other parts of the range apparently did not benefit in the same way. Land transformation in the Grassland biome generally takes the form of urbanisation, afforestation or cultivation, and much of the area is also classified as "degraded" in the NLC maps (Figure 5b in Chapter 1) (CSIR and ARC 2005, SANBI 2009). Degraded land cover is defined as vegetation cover which has been permanently or near-permanently severely reduced by man, and is generally associated with subsistence agriculture, overgrazing and wood removal (CSIR and ARC 2005). None of these forms of land transformation, except for some types of cultivation at certain times of the year (e.g. pasture and crop stubble in winter, Figure 3), constitute suitable habitat for bustards, in contrast to the situation in the Fynbos biome.

SABAP comparison map

The SABAP comparison map (Figure 4) confirmed the results of the population trend analysis, and further suggested that almost the entire population north of 33°30' S declined to some extent between SABAP1 and SABAP2. There were many grid cells with zero reporting rates for SABAP2 in this part of the species' range. These often did not show up as significant (red or orange) in Figure 4 because SABAP1 reporting rates were already very small. This may therefore represent a large area of range contraction for this species. In some areas, however, such as in the Eastern Cape, the number of SABAP2 lists submitted by the date on which the map was extracted was small (Figure 3b in Chapter 1), so conclusions for these areas should remain tentative.

The relationship of atlas reporting rates to abundance, and the likelihood of underestimation of range contraction in the comparison of SABAP1 data with SABAP2, are discussed in Chapter 3. According to Griffioen's (2001) conversion for reporting rates, used in calculating the national population index, reporting rates are related to density in a near-linear fashion for reporting rates of zero to 60%. Reporting rates for Denham's Bustards exceeded 60% in only two QDGCs, for SABAP2, and exceeded 50% in either of the SABAP projects in six QDGCs. Thus it is likely that in areas with good SABAP2 coverage the observed decreases in reporting rates represent real decreases in abundance (and vice versa for increases).

National population index

The different sets of weights changed the influence of the precincts according to their importance with respect to the Denham's Bustard population as a whole, according to different measures. Unusually large densities of Denham's Bustards were recorded in the Eastern Cape Coastal precinct in the CAR project, so although this is a relatively small precinct (total road length of 370 km, Table A3.1), it was over-represented in comparison to the other precincts when all precincts were equally weighted. Area weights addressed this issue. The Little Karoo was neutrally weighted by the area weights, because it was similar in size to two of the other precincts, but it was severely down-weighted by the weights incorporating reporting rate, because the SABAP1 reporting rate for the species was minimal in this area. The North-eastern Eastern Cape, where a small density of Denham's Bustards was recorded in the CAR project, was heavily weighted by all unequal weights, because both its area and the SABAP1 reporting rate were relatively large compared to the other precincts (Appendix 3, Table A3.3). The weights that involved both area and reporting rate were almost identical, so applying Griffioen's (2001) conversion had very little effect.

The national population index for Denham's Bustards suggest that the portion of the population covered by the CAR project remained stable or increased slightly overall between 1993 and 2010 (Figure 5). The large degree of inter-annual variability reflects the variability in CAR count totals. The winter 2003 peak was caused by the unusually large density of Denham's Bustards recorded in the Little Karoo precinct in that CAR count; this explains why the peak was most pronounced for the equally and area-weighted indices, and much reduced for the indices whose weights incorporated reporting rate. The summer 2007 peak was caused by the unusually large numbers of birds recorded in the Eastern Cape Coastal, North-eastern Eastern Cape and especially the Overberg precincts in that count. These peaks were no doubt related to the semi-nomadic and seasonal flocking behaviour of the species, and further illustrate the challenges inherent in monitoring this species effectively.

From 1993 to 1996 only one precinct was surveyed, and in 1997 this increased to two. Four of the precincts were surveyed from 1998, and the Little Karoo surveys began in 2000. The indices for the years prior to 1998 are therefore based mostly on densities obtained in CAR surveys done in other years, and are thus less reliable. This is an unavoidable issue when dealing with data from public participation projects.

Only c. 32% of the species' range was covered by the national population index analysis. This is partly because several CAR precincts in which the species occurred had to be excluded from the population trend analysis due to insufficient data. If all of these precincts could have been included, c. 57% of the range would be covered. The main parts of the range that would still not be covered are in the central and south-western Eastern Cape, in KwaZulu-Natal to the east of the areas already covered, in Mpumalanga mainly to the east of the Steenkampsberg and Mpumalanga precincts, and in Limpopo. In the majority of the area not covered in this analysis the SABAP comparison map shows decreased reporting rates for SABAP2 (Figure 4). The trend for the population as a whole is therefore likely to be less positive than the national population indices suggest, and possibly decreasing.

For this analysis only SABAP1 reporting rates were used, because SABAP2 coverage as of January 2012 was not yet sufficient to provide reliable reporting rates for the whole of the Denham's Bustard's range. However, in this SABAP2 data some reporting rates had almost doubled (Eastern Cape Coastal, Little Karoo) and others had almost halved (Southern KwaZulu-Natal; SABAP2 unpubl. data). Thus as SABAP2 coverage improves, this analysis should be updated to incorporate SABAP2 reporting rates into the weights (Chapter 4). It is also likely that data from more CAR precincts will become usable as the project continues, and this would improve the quality of the national index significantly.

General

The 2010 assessment of threats faced by South Africa's bustard species (Table 1 in Chapter 1) (Allan and Anderson 2010) concluded that the Denham's Bustard was the most severely threatened of all of South Africa's bustard species. The most important threat to Denham's Bustards was assessed as collisions with overhead powerlines. While it is not possible to assess the direct impact of powerline collisions on the population using the data presented here, it would seem that it is at least not a serious threat in the Western Cape and along the southern coastal belt of the Eastern Cape, judging by the fact that the population there did not decline over the study period. However, the density of powerlines in the majority of the rest of the range is higher than in this area (Figure 6) (Brits 2007), so this could be a major factor in the decline of the species in the rest of its range. A recent study found that Blue Cranes in the Overberg region were suffering potentially unsustainable mortality rates due to powerline collisions, but that at present the rate of population growth in this area was sufficient to absorb these losses (Shaw et al. 2010). In counts of carcasses under powerlines, the number of Blue Crane carcasses found was approximately five times the number of Denham's Bustard carcasses, the next most common species found (Shaw 2009). Considering that numbers of Blue Cranes seen per 100 km of road were between 20 (winter) and 50 (summer) times the number of Denham's Bustards in 2010, this suggests that the proportional impact of powerline collisions on the Denham's Bustard population is many times more severe. At present it seems the Overberg population is able to sustain this level of mortality, but in the parts of the range to the north-east this is unlikely to be the case.

The other threats were mainly associated with land cover change (habitat destruction) and disturbance by humans and their domestic animals (Allan and Anderson 2010). The present study provides support for the idea that habitat destruction is an important threat to Denham's Bustards in the part of their range outside the Fynbos and Albany Thicket biomes. Climate change was also assessed as a potential threat. Climate change is predicted to affect the south-west of South Africa more severely than the rest of the country (Huntley et al. 2006, Dai 2011), to cause severe droughts and existing vegetation types and climatic zones to shift south and west, and eventually disappear. It has also been suggested that large-bodied species may be at particular risk from climate change because their long generation times limit their ability to adapt quickly, although in the short term their ability to move easily and to survive short-term food shortages may be a benefit (Simmons et al. 2004). Climate change could therefore have a serious effect on the Denham's Bustard, because the region predicted to be under the most threat from climate change is the only part of its range where it did not decline during the study period. Given the species' extensive use of transformed land in this region, the effects of any changes in farming practices which may occur as a result of changing climatic conditions could be severe.

Conclusions

The partially nomadic, seasonally flocking behaviour of this species makes it difficult to monitor its abundance effectively in some areas with a project such as CAR. The habitat use data collected by observers however are useful for understanding some of the requirements of the species and reasons for its decline. The bird atlas project has provided useful and meaningful results for population trend analysis. Although the national population index in the present study was not particularly conclusive and may not present an accurate representation of the status of the whole *stanleyi* subspecies population, it is likely that it will become more useful as both SABAP2 coverage and CAR data increase.

Bird atlas data indicate that this subspecies decreased in abundance throughout most of its range between the data collection periods of SABAP1 and SABAP2. Given the vulnerability of the region where it did not decrease to climate change impacts, and the vulnerability of the species to changing land-use practices, it is recommended that this subspecies remain on the South African Red Data list in the Vulnerable category. Furthermore, the status of this subspecies should be taken into consideration when reassessing the global threat status of the species as a whole. All possible measures for mitigation of threats should be taken, especially powerline marking and training of land owners in bustard-friendly land management techniques (Chapter 7). More intensive monitoring is also recommended, as well as increasing the coverage of both the CAR project and SABAP2.

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Table 1: Summary of population trend analysis data for the Denham's Bustard from the Coordinated Avifaunal Roadcounts (CAR) project. The column "Number of routes" gives the number of routes surveyed at least six times in either summer or winter. Average route lengths were calculated from these routes. "Number of years" gives the longest series used in the analysis. "Start year" gives the earliest year from which data were used for this analysis. "Total Denham's Bustards" gives the total number of birds seen in these precincts on all routes and in both summer and winter, from the first year in which the precinct was surveyed until 2010 inclusive. Figures are only included for analysed precincts, even though small numbers of birds may have been recorded in other precincts.

Precinct	Number of routes	Ave. route length (km)	Start year	Number of years	Total Denham's Bustards
Eastern Cape Coastal	7	52.9	1998	13	1 663
Little Karoo	8	47.6	2000	11	459
North-eastern Eastern Cape	20	54. 8	1998	13	591
Overberg	33	54.7	1993	18	4 658
Southern KwaZulu-Natal	20	56.2	1997	14	927
Total	88	54.3			8 298

Table 2: Adjustments made to Denham's Bustard data used for the Underhill index analysis. Adjustments were only necessary for summer data.

Precinct	Adjustment	Comments
Little Karoo	2000 excluded	Too few routes were surveyed this year for the imputed totals to be realistic
North-eastern Eastern Cape	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
	1998 excluded	Too few routes were surveyed this year for the imputed totals to be realistic

Table 3: Habitat selection analysis of Denham's Bustard CAR data for the Overberg, Little Karoo, Eastern Cape Karoo, Eastern Cape Coastal, North-eastern Eastern Cape, Eastern Karoo, North-eastern Free State, Northern KwaZulu-Natal, Southern KwaZulu-Natal, Steenkampsberg and Wakkerstroom precincts, summer (S) and winter (W) counts. Jacobs index *D* values indicate selection for natural habitat if positive and for transformed land if negative. Numbers in the Natural and Transformed columns are the numbers of routes on which a preference was shown for natural and transformed habitats respectively. Sign test *p* values refer to tests of whether the number of routes with positive Jacobs index *D* values was significantly different from that expected if zero selection had been shown.

Precinct	Season	Jacobs index *D*	Natural	Transformed	Sign test *p* value
Eastern Cape Coastal	S	–0.264	5	5	1.000
	W	–0.175	7	4	0.366
Eastern Cape Karoo	S	–0.428	10	2	0.021
	W	–0.793	7	3	0.206
Eastern Karoo	S	1.000	9	0	0.003
	W	1.000	7	0	0.008
Little Karoo	S	–0.534	1	6	0.059
	W	–0.593	2	5	0.257
North-eastern Eastern Cape	S	0.430	13	5	0.059
	W	–0.252	7	6	0.782
North-eastern Free State	S	0.594	12	1	0.002
	W	0.724	3	1	0.317
Northern KwaZulu-Natal	S	0.527	9	3	0.083
	W	–0.269	9	4	0.166
Overberg	S	–0.403	8	23	0.007
	W	–0.415	6	28	< 0.001
Steenkampsberg	S	1.000	6	0	0.014
	W	–0.833	1	1	1.000
Southern KwaZulu-Natal	S	0.362	16	4	0.007
	W	–0.210	7	15	0.088
Wakkerstroom	S	1.000	3	0	0.083
	W	–0.013	4	2	0.414

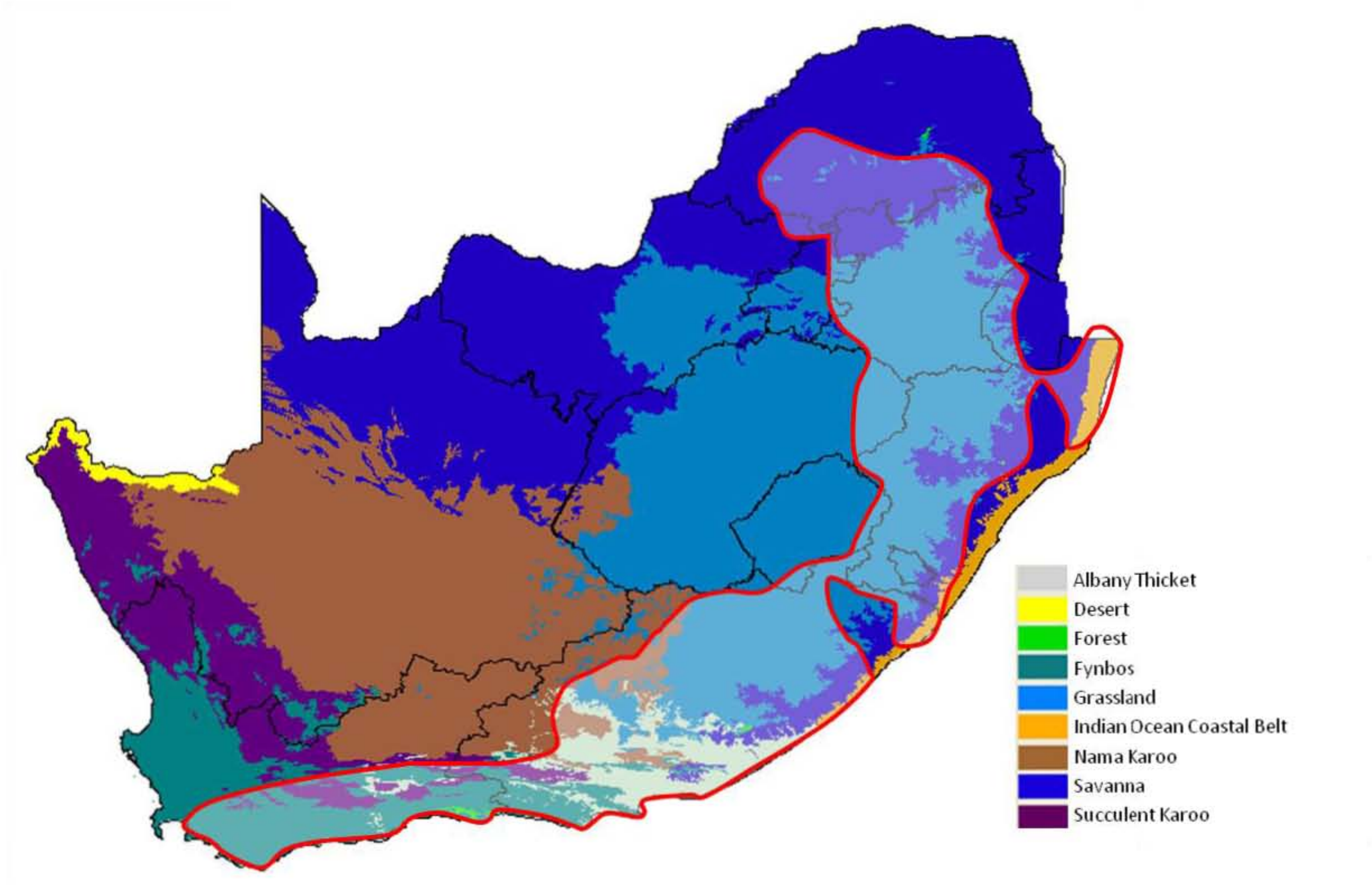


Figure 1a: Biomes (Mucina and Rutherford 2006) and outline of the range of the Denham's Bustard, drawn using data from SABAP1 (Allan 1997) and SABAP2 (presented below).

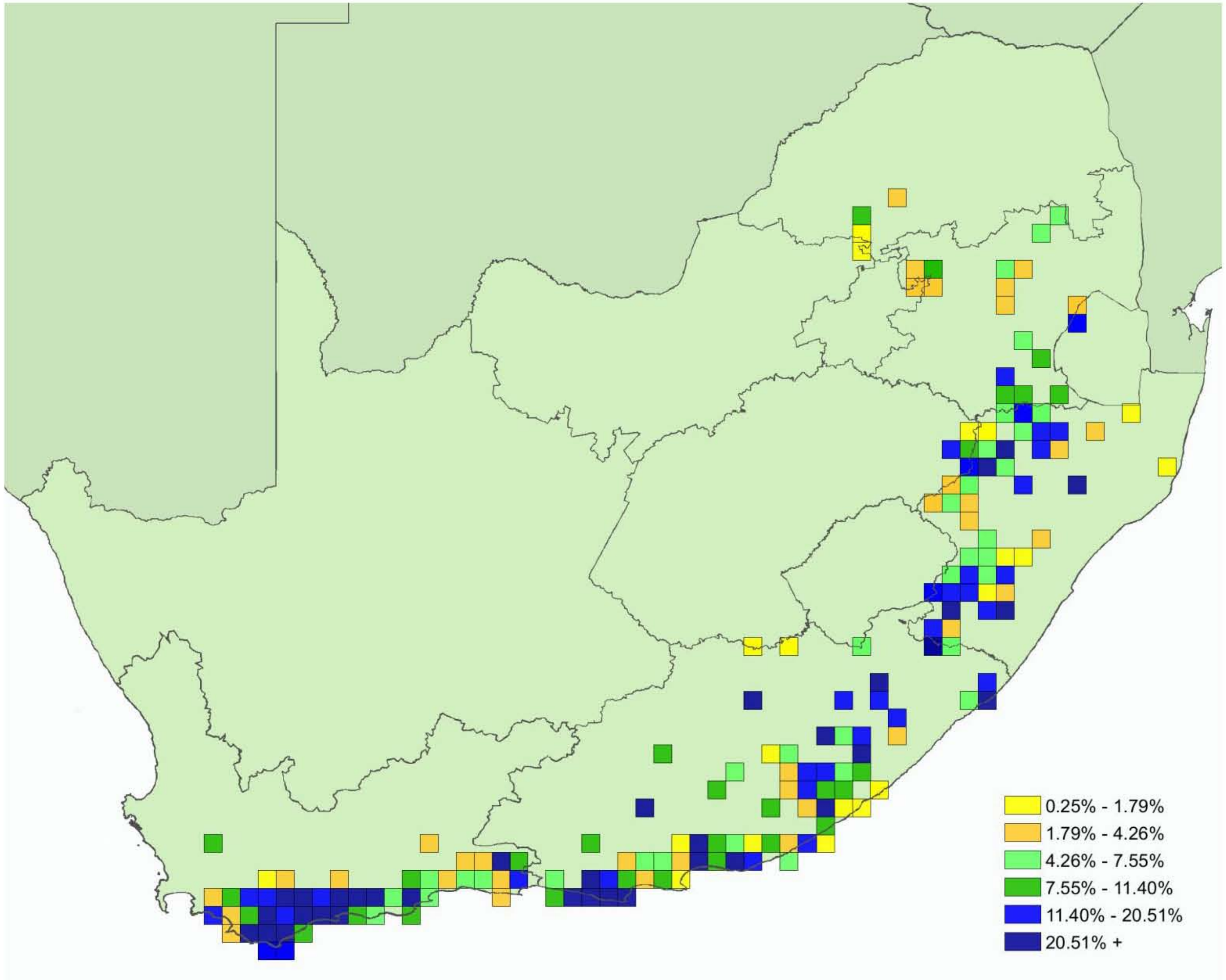


Figure 1b: Range map for the Denham's Bustard showing derived reporting rates calculated from SABAP1 and SABAP2 data, extracted on 10 February 2012. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15'). Derived reporting rates were calculated as described in Chapter 1.

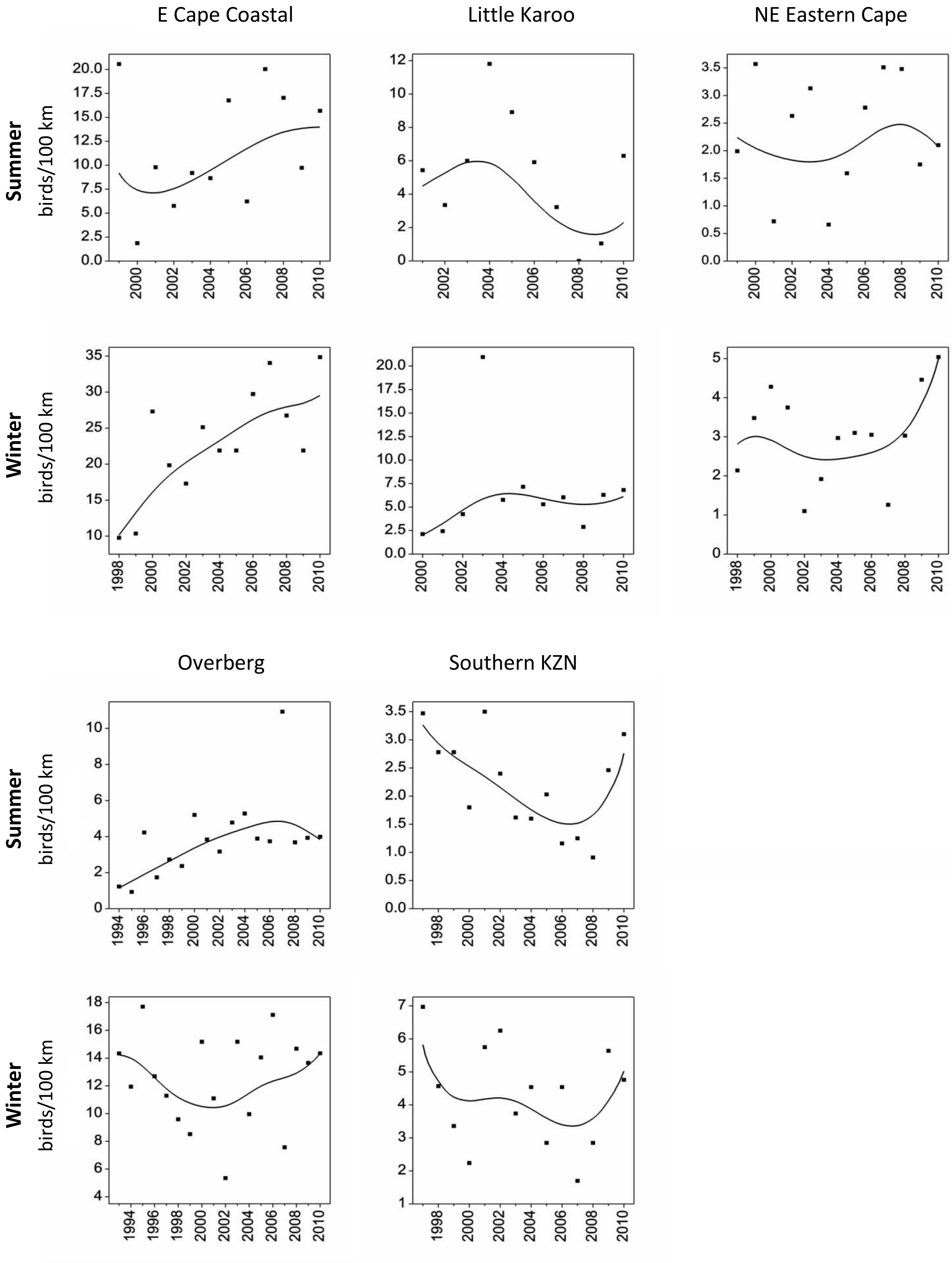


Figure 2: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Denham's Bustard for the Eastern Cape Coastal (370 km), Little Karoo (381 km), North-eastern Eastern Cape (summer: 931 km; winter: 1 096 km), Overberg (summer: 1 806 km; winter: 1 757 km) and Southern KwaZulu-Natal (1 123 km) precincts (Figure 1 in Chapter 1) for summer and winter counts.

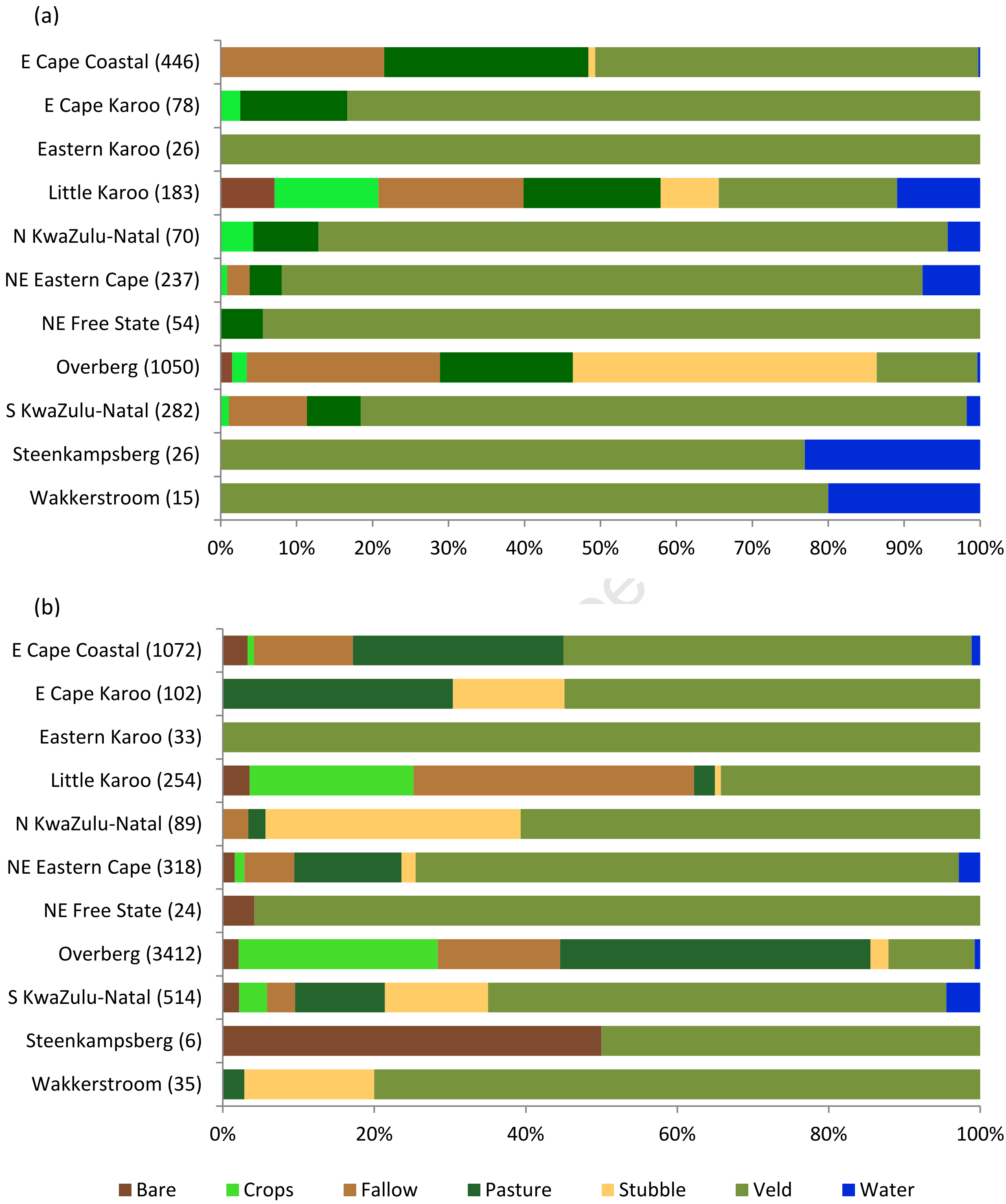


Figure 3: CAR habitat use data for Denham's Bustards for (a) summer and (b) winter counts, for the 11 precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in surveys conducted in that season. "Bare" indicates ploughed land, "stubble" is harvested crop fields, "crops" includes all cultivated crops, orchards and plantations, and "water" includes natural rivers, pans and wetlands as well as man-made water reservoirs.

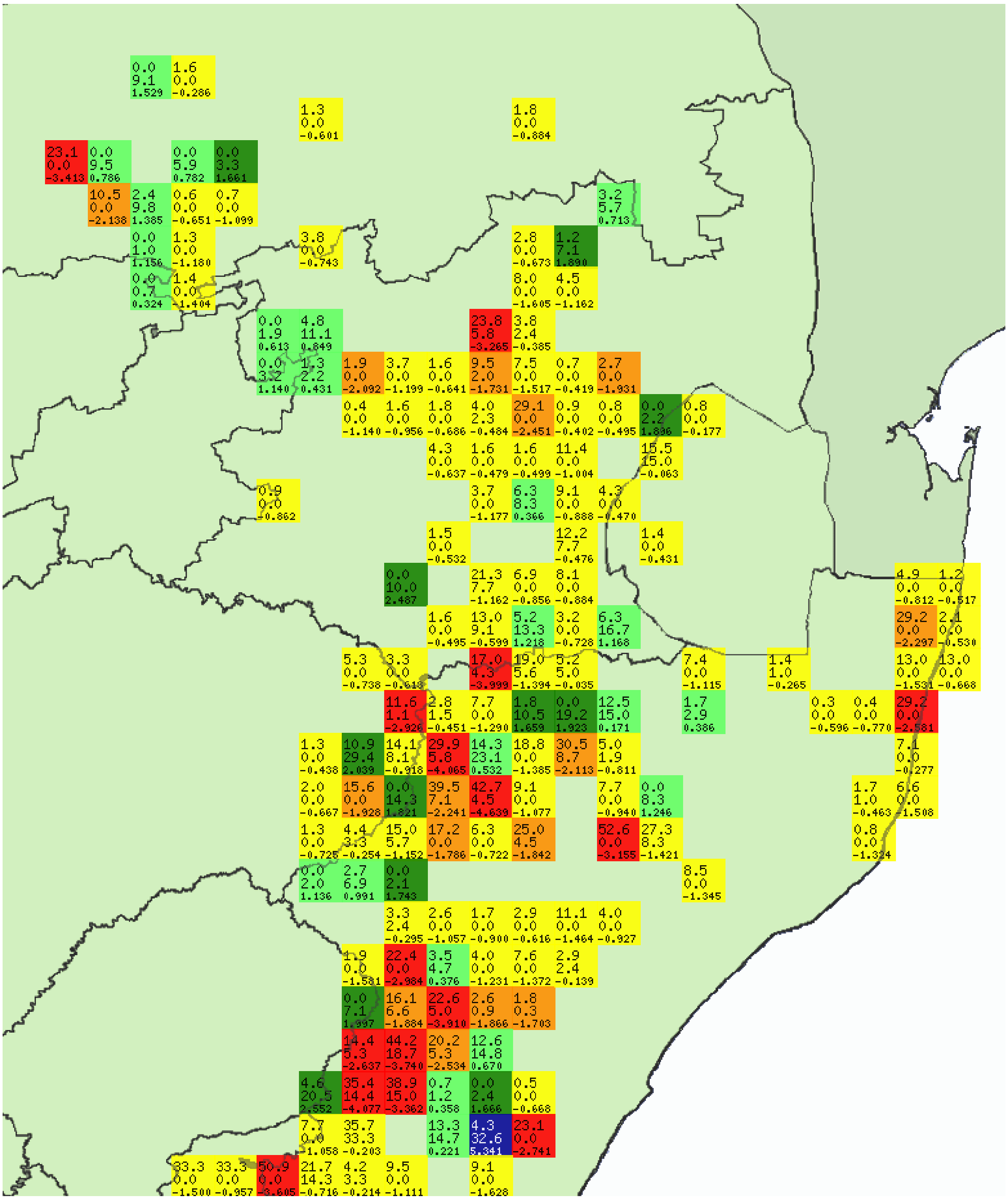


Figure 4a: SABAP comparison map for the Denham's Bustard, extracted on 10 February 2012, for the part of the range north of 30º30' S. This map compares SABAP1 and SABAP2 reporting rates. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15') in which the species was observed in either project. Reporting rates are compared using the Z statistic (see text). The upper number in each square is the SABAP1 reporting rate, the middle number is the SABAP2 reporting rate, and the lower number is Z. SABAP2 reporting rates for were lower than SABAP1 in red, orange and yellow grid cells, and higher than SABAP1 in light and dark green and blue grid cells. In red grid cells $Z < -2.58$, in orange $-2.58 < Z < -1.64$, and in yellow $-1.64 < Z < 0$. In light green grid cells $0 \leq Z < 1.64$, in dark green $1.64 < Z < 2.58$, and in blue grid cells $Z > 2.58$. Pink grid cells are those which had not yet been covered in SABAP2. Therefore, red, orange and yellow grid cells indicate areas of potential conservation concern, whereas green and blue grid cells indicate areas of apparent population increase.

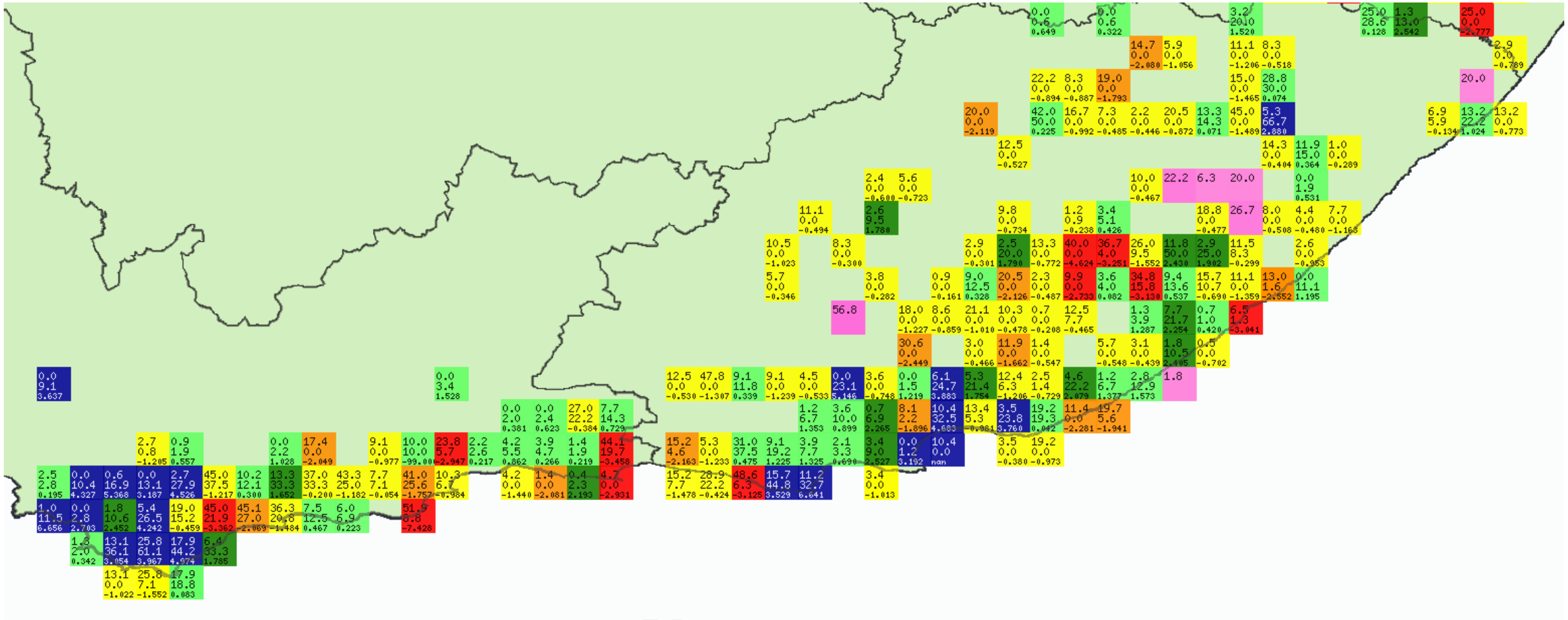


Figure 4b: SABAP comparison map for the Denham's Bustard, extracted on 10 February 2012, for the part of the range south of 30º30' S. Produced as for Figure 4a.

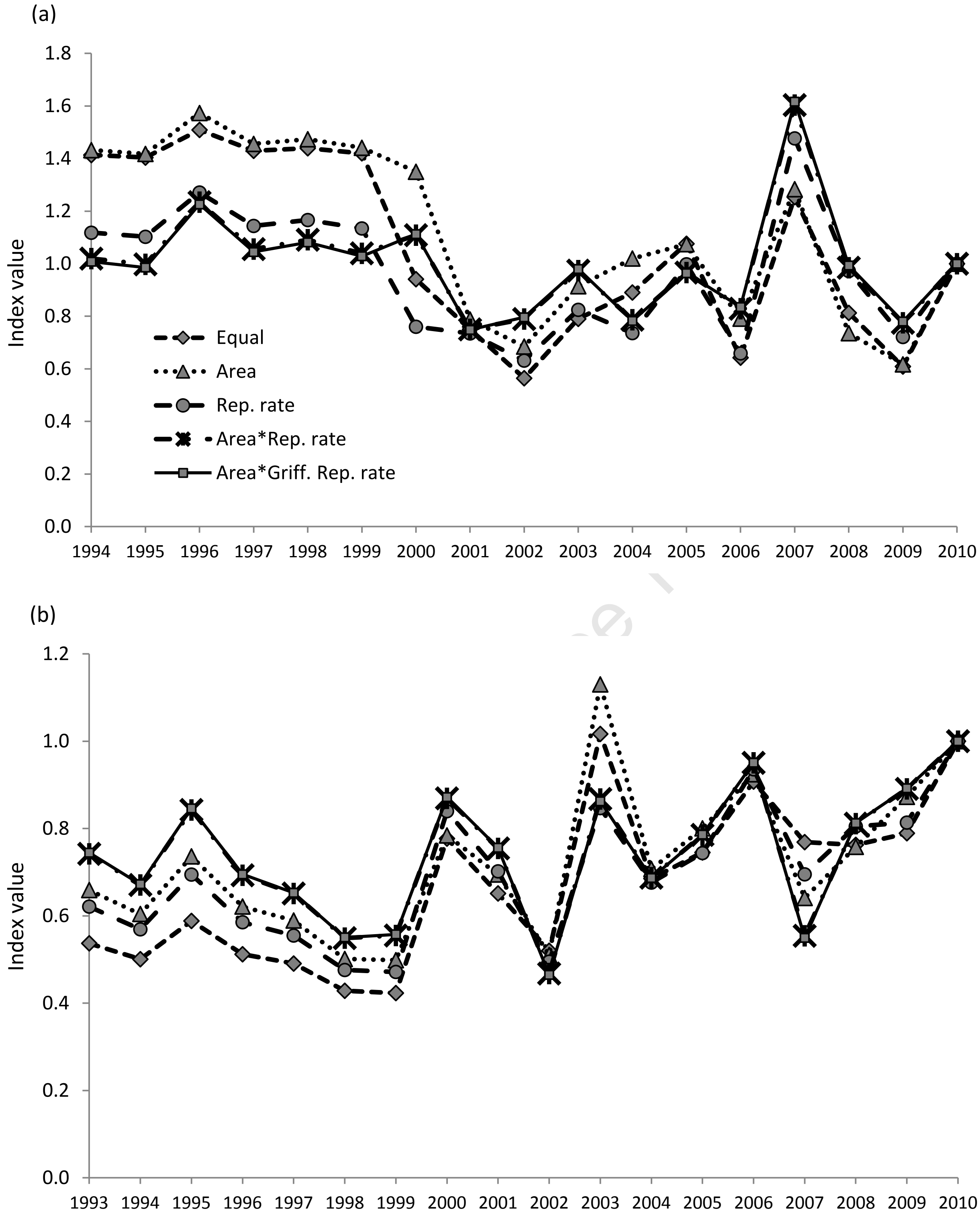


Figure 5: National indices for Denham's Bustards for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weights, each one represented by one set of points and a line. "Equal" had equal weights for each precinct. "Area" had precincts weighted by their relative area, and "Rep. rate" had precincts weighted by SABAP1 reporting rates for Southern Black Korhaans for that precinct. "Area*Rep. rate" weights used area and reporting rate multiplied together, and "Area*Griff. Rep. rate" used area multiplied by the logarithmic conversion of reporting rates suggested by Griffioen (2001).

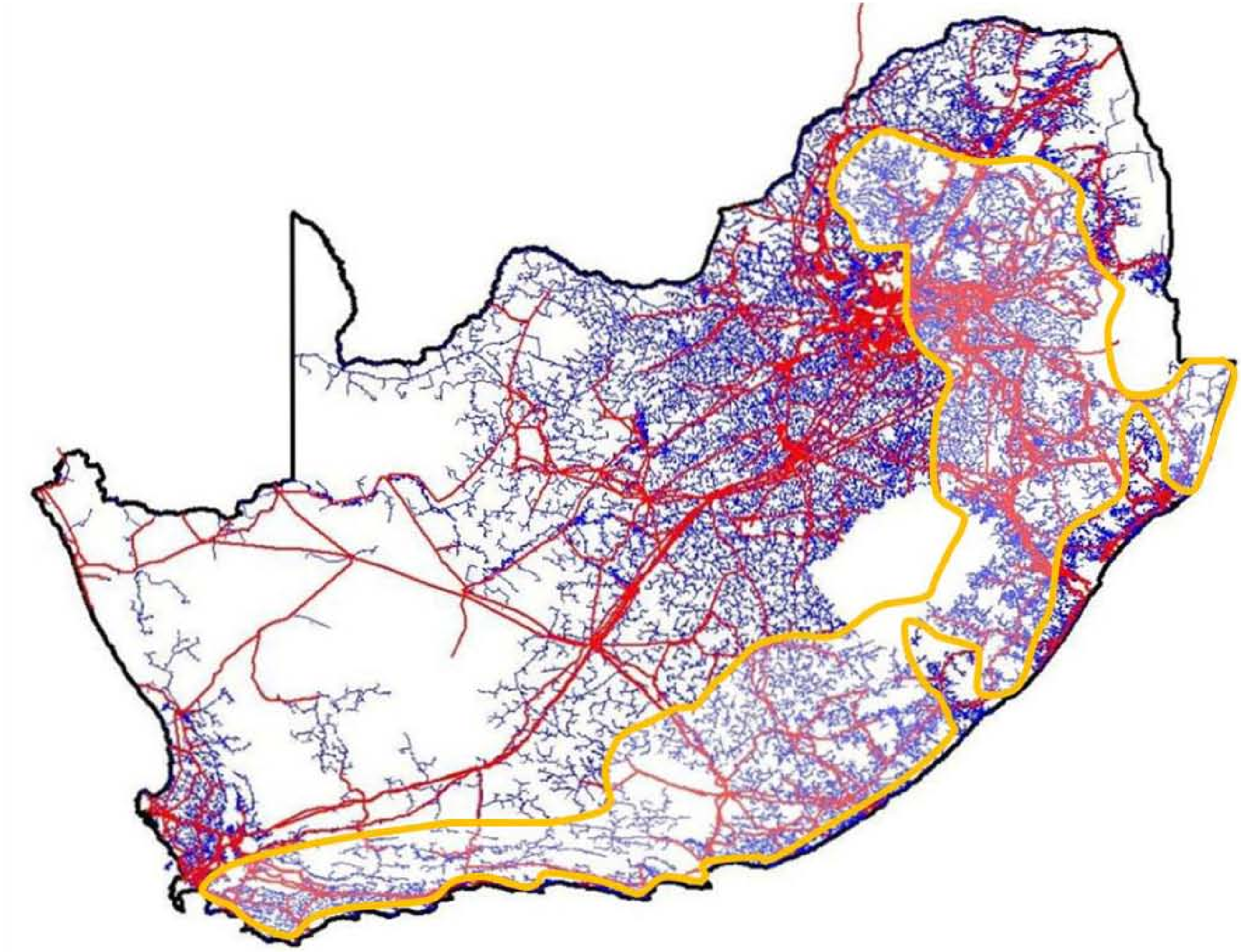


Figure 6: Distribution of powerlines in South Africa (Brits, 2007) and outline of the range of Denham's Bustard (yellow line; drawn as for Figure 1a).

Appendix 3. Supplementary data for Chapter 5

Table A3.1: Results of population trend analysis of CAR project data for Denham's Bustards for the five precincts in which the number of birds recorded attained the criteria for inclusion (see text): Eastern Cape Coastal, Little Karoo, North-eastern Eastern Cape, Overberg and Southern KwaZulu-Natal. "Birds/100 km" columns give the count totals estimated using the Underhill index, converted to birds per 100 km of road surveyed; "incr" columns show the percent change in population per year, calculated as the slope of the weighted linear regressions; "Δ incr" columns show the change in increment from one year to the next (see text). R^2 values give the proportion of the variance of the totals that is explained by the trend line; SD is the standard deviation of the totals, CV is the coefficient of variation, and "% imp" values indicate the percentage of the overall total that was imputed using the Underhill index. Distance gives the distance in kilometres of the routes included in each analysis. For uniformity, all results are presented to two decimal places.

Eastern Cape Coastal

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				9.77	0.24	
1999	20.56	–0.13		10.36	0.19	–0.05
2000	1.87	–0.03	0.10	27.31	0.14	–0.05
2001	9.79	0.05	0.08	19.84	0.10	–0.04
2002	5.76	0.10	0.05	17.30	0.08	–0.03
2003	9.19	0.12	0.02	25.13	0.07	–0.01
2004	8.65	0.12	0.00	21.89	0.06	0.00
2005	16.76	0.11	–0.01	21.89	0.06	0.00
2006	6.22	0.09	–0.02	29.73	0.05	–0.01
2007	20.03	0.07	–0.02	34.05	0.03	–0.02
2008	17.03	0.05	–0.02	26.75	0.02	–0.01
2009	9.73	0.03	–0.02	21.89	0.02	0.00
2010	15.68	0.02	–0.01	34.86	0.03	0.01
Mean	11.77	0.05		23.14	0.08	
R^2	0.27			0.69		
SD	6.05			7.78		
CV	51.41			33.62		
% imp	18.11			15.27		
Distance (km)	370.01			370.01		

Little Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
2000				2.13	0.47	
2001	5.44	0.14		2.44	0.38	–0.09
2002	3.35	0.10	–0.04	4.25	0.26	–0.12
2003	6.00	0.01	–0.09	20.96	0.13	–0.13
2004	11.81	–0.11	–0.12	5.77	0.02	–0.11
2005	8.92	–0.22	–0.11	7.16	–0.05	–0.07
2006	5.92	–0.29	–0.07	5.30	–0.07	–0.02
2007	3.23	–0.30	–0.01	6.04	–0.06	0.01
2008	0.00	–0.24	0.07	2.89	–0.03	0.04
2009	1.05	–0.08	0.15	6.30	0.02	0.05
2010	6.30	0.17	0.25	6.82	0.08	0.05
Mean	5.20	–0.08		6.37	0.11	
R^2	0.44			0.44		
SD	3.52			5.15		
CV	67.67			80.89		
% imp	7.18			3.73		
Distance (km)	381.06			381.06		

North-eastern Eastern Cape

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				2.14	0.03	
1999	1.99	–0.07		3.48	–0.03	–0.06
2000	3.57	–0.06	0.01	4.28	–0.07	–0.04
2001	0.72	–0.04	0.02	3.75	–0.07	0.00
2002	2.63	–0.03	0.02	1.10	–0.05	0.03
2003	3.13	0.00	0.03	1.92	–0.01	0.04
2004	0.66	0.05	0.04	2.97	0.02	0.03
2005	1.59	0.09	0.04	3.10	0.03	0.01
2006	2.78	0.11	0.01	3.05	0.05	0.01
2007	3.51	0.08	–0.03	1.26	0.08	0.04
2008	3.48	0.02	–0.06	3.03	0.14	0.06
2009	1.75	–0.04	–0.06	4.46	0.20	0.06
2010	2.10	–0.09	–0.05	5.04	0.25	0.05
Mean	2.33	0.00		3.04	0.04	
R^2	0.13			0.31		
SD	1.03			1.20		
CV	44.25			39.45		
% imp	24.91			19.50		
Distance (km)	931.37			1095.55		

Year	Overberg Summer			Overberg Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1993				14.34	–0.03	
1994	1.23	0.25		11.94	–0.04	–0.02
1995	0.93	0.22	–0.04	17.71	–0.06	–0.01
1996	4.23	0.18	–0.03	12.69	–0.06	–0.01
1997	1.74	0.15	–0.03	11.29	–0.06	0.01
1998	2.73	0.14	–0.02	9.59	–0.04	0.01
1999	2.37	0.12	–0.02	8.52	–0.03	0.02
2000	5.20	0.10	–0.02	15.18	–0.01	0.01
2001	3.84	0.08	–0.02	11.10	0.00	0.02
2002	3.17	0.06	–0.02	5.35	0.02	0.02
2003	4.78	0.05	–0.01	15.18	0.04	0.02
2004	5.28	0.05	–0.01	9.96	0.05	0.00
2005	3.89	0.04	–0.01	14.05	0.04	–0.01
2006	3.74	0.02	–0.02	17.12	0.02	–0.01
2007	10.93	–0.01	–0.03	7.57	0.02	0.00
2008	3.68	–0.04	–0.03	14.68	0.03	0.01
2009	3.93	–0.07	–0.03	13.66	0.04	0.01
2010	3.99	–0.09	–0.02	14.35	0.05	0.01
Mean	3.86	0.07		12.46	0.00	
R^2	0.59			0.18		
SD	2.22			3.33		
CV	57.49			26.70		
% imp	10.28			9.72		
Distance (km)	1805.97			1757.19		

Year	Southern KwaZulu-Natal Summer			Southern KwaZulu-Natal Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1997	3.47	–0.09		6.97	–0.15	
1998	2.78	–0.07	0.01	4.57	–0.09	0.06
1999	2.78	–0.06	0.01	3.36	–0.03	0.06
2000	1.80	–0.06	0.00	2.24	0.01	0.04
2001	3.50	–0.07	–0.01	5.75	0.02	0.01
2002	2.40	–0.09	–0.01	6.25	–0.01	–0.02
2003	1.62	–0.09	–0.01	3.74	–0.04	–0.03
2004	1.60	–0.09	0.00	4.54	–0.06	–0.02
2005	2.03	–0.07	0.02	2.85	–0.07	0.00
2006	1.16	–0.03	0.04	4.54	–0.04	0.03
2007	1.25	0.02	0.06	1.70	0.01	0.05
2008	0.91	0.10	0.08	2.85	0.07	0.06
2009	2.46	0.19	0.09	5.64	0.13	0.06
2010	3.10	0.28	0.09	4.76	0.18	0.05
Mean	2.20	–0.01		4.27	–0.01	
R^2	0.61			0.31		
SD	0.85			1.56		
CV	38.66			36.55		
% imp	17.15			7.77		
Distance (km)	1122.98			1122.98		

Table A3.2: Habitat selection by Denham's Bustards (DBs) using Coordinated Avifaunal Roadcounts (CAR) data for the Eastern Cape Coastal, Eastern Cape Karoo, Eastern Karoo, North-eastern Eastern Cape, Little Karoo, North-eastern Free State, Northern KwaZulu-Natal, Overberg, Southern KwaZulu-Natal, Steenkampsberg and Wakkerstroom precincts (Figure 1 in Chapter 1). "Land area" sections give the percentage of each type of land cover (natural or transformed) within a 3 000 m wide buffer zone around each route, as calculated from the National Land-Cover maps for 1994, 2000 and 2009 (NLC1994, NLC2000 and NLC2009 respectively). "No. DBs" columns give numbers of birds seen in each habitat type on these routes over the whole count period (1993–2010). "Jacobs index" columns give the values calculated for this index; *r* is the proportion of birds seen in natural habitat to the total number of birds seen on that route, *p* is the proportion of the area of natural habitat to the total land area, calculated as the average of the three NLC values, and *D* is the index, calculated using the formula presented in Jacobs (1974). Positive values for *D* indicate selection for natural habitat, negative the reverse. The bottom row contains the overall percentages of each habitat type for each map, the percentage of birds seen in each habitat type, the total number of birds on which the analysis is based (underlined), and the Jacobs index for the whole precinct (excluding routes on which the species has never been seen).

Eastern Cape Coastal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EH01	62.55	37.45	70.80	29.20	66.17	33.83	15	4	**19**	0.79	0.67	**0.31**
EH02	30.42	69.58	21.34	78.66	13.46	86.54	2	12	**14**	0.14	0.22	**–0.25**
EH03	27.98	72.02	16.40	83.60	11.78	88.22	20	99	**119**	0.17	0.19	**–0.07**
EH05	60.44	39.56	67.76	32.24	63.04	36.96	35	2	**37**	0.95	0.64	**0.82**
EH06	31.32	68.68	20.84	79.16	12.53	87.47	51	86	**137**	0.37	0.22	**0.37**
EK01	89.63	10.37	94.95	5.05	86.02	13.98	10	0	**10**	1.00	0.90	**1.00**
EK02	75.91	24.09	90.97	9.03	70.71	29.29	24	7	**31**	0.77	0.79	**–0.05**
EK03	77.07	22.93	85.69	14.31	59.90	40.10	7	1	**8**	0.88	0.74	**0.42**
EK04	90.04	9.96	95.95	4.05	86.33	13.67	34	6	**40**	0.85	0.91	**–0.27**
EK05	74.83	25.17	90.65	9.35	65.45	34.55	28	26	**54**	0.52	0.77	**–0.51**
Overall	**63.32**	**36.68**	**66.91**	**33.09**	**54.28**	**45.72**	**48.19**	**51.81**	**<u>469</u>**	**0.48**	**0.62**	**–0.26**

Eastern Cape Coastal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EH01	62.55	37.45	70.80	29.20	66.17	33.83	46	23	**69**	0.67	0.67	**0.00**
EH02	30.42	69.58	21.34	78.66	13.46	86.54	27	80	**107**	0.25	0.22	**0.10**
EH03	27.98	72.02	16.40	83.60	11.78	88.22	101	150	**251**	0.40	0.19	**0.49**
EH04	70.42	29.58	71.01	28.99	64.49	35.51	19	18	**37**	0.51	0.69	**–0.35**
EH05	60.44	39.56	67.76	32.24	63.04	36.96	86	11	**97**	0.89	0.64	**0.63**
EH06	31.32	68.68	20.84	79.16	12.53	87.47	190	186	**376**	0.51	0.22	**0.58**
EK01	89.63	10.37	94.95	5.05	86.02	13.98	14	0	**14**	1.00	0.90	**1.00**
EK02	75.91	24.09	90.97	9.03	70.71	29.29	12	14	**26**	0.46	0.79	**–0.63**
EK03	77.07	22.93	85.69	14.31	59.90	40.10	4	12	**16**	0.25	0.74	**–0.79**
EK04	90.04	9.96	95.95	4.05	86.33	13.67	30	3	**33**	0.91	0.91	**0.01**
EK05	74.83	25.17	90.65	9.35	65.45	34.55	61	19	**80**	0.76	0.77	**–0.02**
Overall	**63.75**	**36.25**	**67.15**	**32.85**	**54.89**	**45.11**	**53.35**	**46.65**	**<u>1106</u>**	**0.53**	**0.62**	**–0.17**

Eastern Cape Karoo summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EG01	98.52	1.48	99.88	0.12	98.80	1.20	6	0	**6**	1.00	0.99	**1.00**
EG02	94.55	5.45	99.03	0.97	98.13	1.87	5	0	**5**	1.00	0.97	**1.00**
EM01	96.98	3.02	95.57	4.43	98.36	1.64	2	0	**2**	1.00	0.97	**1.00**
EP02	99.28	0.72	98.25	1.75	98.27	1.73	3	0	**3**	1.00	0.99	**1.00**
EP03	98.88	1.12	90.69	9.31	97.01	2.99	7	0	**7**	1.00	0.96	**1.00**
EP06	87.10	12.90	71.07	28.93	81.88	18.12	29	2	**31**	0.94	0.80	**0.57**
EP09	73.37	26.63	63.44	36.56	74.98	25.02	2	0	**2**	1.00	0.71	**1.00**
EP11	67.10	32.90	69.17	30.83	66.80	33.20	4	11	**15**	0.27	0.68	**–0.70**
ES03	94.45	5.55	96.72	3.28	95.89	4.11	0	1	**1**	0.00	0.96	**–1.00**
ES04	96.73	3.27	97.31	2.69	97.02	2.98	3	0	**3**	1.00	0.97	**1.00**
ES05	93.27	6.73	94.34	5.66	90.25	9.75	2	0	**2**	1.00	0.93	**1.00**
ES07	97.95	2.05	99.44	0.56	98.63	1.37	2	0	**2**	1.00	0.99	**1.00**
Overall	**92.72**	**7.28**	**91.17**	**8.83**	**92.30**	**7.70**	**82.28**	**17.72**	**79**	**0.82**	**0.92**	**–0.43**

Eastern Cape Karoo winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EG01	98.52	1.48	99.88	0.12	98.80	1.20	9	0	**9**	1.00	0.99	**1.00**
EG02	94.55	5.45	99.03	0.97	98.13	1.87	3	0	**3**	1.00	0.97	**1.00**
EG03	98.15	1.85	99.02	0.98	98.17	1.83	4	0	**4**	1.00	0.98	**1.00**
EM01	96.98	3.02	95.57	4.43	98.36	1.64	1	2	**3**	0.33	0.97	**–0.97**
EP06	87.10	12.90	71.07	28.93	81.88	18.12	10	34	**44**	0.23	0.80	**–0.86**
EP07	99.60	0.40	92.55	7.45	97.73	2.27	4	0	**4**	1.00	0.97	**1.00**
EP09	73.37	26.63	63.44	36.56	74.98	25.02	2	0	**2**	1.00	0.71	**1.00**
EP11	67.10	32.90	69.17	30.83	66.80	33.20	7	9	**16**	0.44	0.68	**–0.46**
ES03	94.45	5.55	96.72	3.28	95.89	4.11	7	0	**7**	1.00	0.96	**1.00**
ES05	93.27	6.73	94.34	5.66	90.25	9.75	9	0	**9**	1.00	0.93	**1.00**
Overall	**92.16**	**7.84**	**90.65**	**9.35**	**91.75**	**8.25**	**55.45**	**44.55**	**101**	**0.55**	**0.92**	**–0.79**

Eastern Karoo summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
NK023	96.25	3.75	90.53	9.47	100.00	0.00	6	0	**6**	1.00	0.96	**1.00**
NK032	99.03	0.97	98.83	1.17	100.00	0.00	6	0	**6**	1.00	0.99	**1.00**
NK042	100.00	0.00	97.22	2.78	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK044	100.00	0.00	99.71	0.29	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK073	100.00	0.00	99.36	0.64	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK081	100.00	0.00	99.60	0.40	100.00	0.00	1	0	**1**	1.00	1.00	**1.00**
NK181	99.97	0.03	98.43	1.57	98.95	1.05	1	0	**1**	1.00	0.99	**1.00**
NK183	99.85	0.15	96.83	3.17	97.27	2.73	2	0	**2**	1.00	0.98	**1.00**
NK213	100.00	0.00	96.87	3.13	100.00	0.00	1	0	**1**	1.00	0.99	**1.00**
Overall	**99.48**	**0.52**	**97.46**	**2.54**	**99.51**	**0.49**	**100.00**	**0.00**	**23**	**1.00**	**0.99**	**1.00**

Eastern Karoo winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK032	99.03	0.97	98.83	1.17	100.00	0.00	6	0	**6**	1.00	0.99	**1.00**
NK041	98.69	1.31	98.40	1.60	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK081	100.00	0.00	99.60	0.40	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK181	99.97	0.03	98.43	1.57	98.95	1.05	1	0	**1**	1.00	0.99	**1.00**
NK182	99.45	0.55	94.79	5.21	97.03	2.97	10	0	**10**	1.00	0.97	**1.00**
NK183	99.85	0.15	96.83	3.17	97.27	2.73	2	0	**2**	1.00	0.98	**1.00**
NK282	93.06	6.94	81.56	18.44	94.50	5.50	2	0	**2**	1.00	0.90	**1.00**
Overall	**98.70**	**1.30**	**95.75**	**4.25**	**98.27**	**1.73**	**100.00**	**0.00**	**25**	**1.00**	**0.98**	**1.00**

Little Karoo summer

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
WC01	39.94	60.06	49.55	50.45	51.72	48.28	20	37	**57**	0.35	0.47	**–0.24**
WK01	53.46	46.54	68.38	31.62	60.95	39.05	0	4	**4**	0.00	0.61	**–1.00**
WU01	54.26	45.74	96.96	3.04	92.42	7.58	9	21	**30**	0.30	0.81	**–0.82**
WU02	74.19	25.81	95.08	4.92	78.95	21.05	19	35	**54**	0.35	0.83	**–0.80**
WU04	59.35	40.65	87.58	12.42	70.68	29.32	3	0	**3**	1.00	0.73	**1.00**
WU05	38.68	61.32	51.52	48.48	35.30	64.70	12	20	**32**	0.38	0.42	**–0.09**
WU06	49.20	50.80	67.92	32.08	61.59	38.41	0	3	**3**	0.00	0.60	**–1.00**
Overall	**52.88**	**47.12**	**73.80**	**26.20**	**63.37**	**36.63**	**34.43**	**65.57**	**183**	**0.34**	**0.63**	**–0.53**

Little Karoo winter

Route	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
WC01	39.94	60.06	49.55	50.45	51.72	48.28	20	4	**24**	0.83	0.47	**0.70**
WK01	53.46	46.54	68.38	31.62	60.95	39.05	0	2	**2**	0.00	0.61	**–1.00**
WU01	54.26	45.74	96.96	3.04	92.42	7.58	0	7	**7**	0.00	0.81	**–1.00**
WU02	74.19	25.81	95.08	4.92	78.95	21.05	12	51	**63**	0.19	0.83	**–0.91**
WU04	59.35	40.65	87.58	12.42	70.68	29.32	0	7	**7**	0.00	0.73	**–1.00**
WU05	38.68	61.32	51.52	48.48	35.30	64.70	50	97	**147**	0.34	0.42	**–0.17**
WU07	76.59	23.41	89.82	10.18	81.69	18.31	5	0	**5**	1.00	0.83	**1.00**
Overall	**57.25**	**42.75**	**76.89**	**23.11**	**66.70**	**33.30**	**34.12**	**65.88**	**255**	**0.34**	**0.67**	**–0.59**

North-eastern Eastern Cape summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EB01	84.41	15.59	89.73	10.27	88.72	11.28	46	1	47	0.98	0.88	0.73
EB02	90.91	9.09	92.87	7.13	90.69	9.31	42	5	47	0.89	0.91	–0.12
EB03	90.03	9.97	83.01	16.99	77.48	22.52	12	2	14	0.86	0.84	0.08
EB04	93.78	6.22	95.75	4.25	93.50	6.50	31	3	34	0.91	0.94	–0.24
EB05	89.05	10.95	80.33	19.67	76.58	23.42	1	0	1	1.00	0.82	1.00
EE01	80.53	19.47	85.53	14.47	85.86	14.14	4	2	6	0.67	0.84	–0.45
EE02	58.30	41.70	74.85	25.15	77.99	22.01	1	0	1	1.00	0.70	1.00
EE03	72.61	27.39	70.17	29.83	65.25	34.75	11	0	11	1.00	0.69	1.00
EE05	81.75	18.25	69.74	30.26	69.15	30.85	1	0	1	1.00	0.74	1.00
EE06	75.81	24.19	83.42	16.58	84.59	15.41	0	2	2	0.00	0.81	–1.00
EE08	91.55	8.45	78.58	21.42	74.63	25.37	7	0	7	1.00	0.82	1.00
EE11	94.86	5.14	92.82	7.18	90.14	9.86	1	0	1	1.00	0.93	1.00
EE13	81.38	18.62	86.98	13.02	79.70	20.30	3	0	3	1.00	0.83	1.00
EE14	83.73	16.27	84.25	15.75	77.32	22.68	1	0	1	1.00	0.82	1.00
EE18	82.50	17.50	88.13	11.87	77.45	22.55	30	7	37	0.81	0.83	–0.05
EE19	87.52	12.48	85.21	14.79	85.78	14.22	3	0	3	1.00	0.86	1.00
EQ02	97.22	2.78	46.60	53.40	39.27	60.73	8	0	8	1.00	0.61	1.00
EU01	6.93	93.07	55.58	44.42	55.60	44.40	12	0	12	1.00	0.39	1.00
Overall	**80.34**	**19.66**	**80.50**	**19.50**	**77.65**	**22.35**	**90.68**	**9.32**	**236**	**0.91**	**0.79**	**0.43**

North-eastern Eastern Cape winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EB01	84.41	15.59	89.73	10.27	88.72	11.28	86	8	94	0.91	0.88	0.21
EB02	90.91	9.09	92.87	7.13	90.69	9.31	45	8	53	0.85	0.91	–0.31
EB03	90.03	9.97	83.01	16.99	77.48	22.52	42	48	90	0.47	0.84	–0.71
EB04	93.78	6.22	95.75	4.25	93.50	6.50	33	6	39	0.85	0.94	–0.50
EB05	89.05	10.95	80.33	19.67	76.58	23.42	3	0	3	1.00	0.82	1.00
EE01	80.53	19.47	85.53	14.47	85.86	14.14	1	8	9	0.11	0.84	–0.95
EE02	58.30	41.70	74.85	25.15	77.99	22.01	2	6	8	0.25	0.70	–0.75
EE03	72.61	27.39	70.17	29.83	65.25	34.75	1	9	10	0.10	0.69	–0.91
EE06	75.81	24.19	83.42	16.58	84.59	15.41	7	1	8	0.88	0.81	0.23
EE11	94.86	5.14	92.82	7.18	90.14	9.86	2	0	2	1.00	0.93	1.00
EE17	73.24	26.76	71.19	28.81	70.74	29.26	4	0	4	1.00	0.72	1.00
EE18	82.50	17.50	88.13	11.87	77.45	22.55	2	0	2	1.00	0.83	1.00
EU01	6.93	93.07	55.58	44.42	55.60	44.40	9	8	17	0.53	0.39	0.27
Overall	**76.10**	**23.90**	**82.34**	**17.66**	**80.23**	**19.77**	**69.91**	**30.09**	**339**	**0.70**	**0.80**	**–0.25**

North-eastern Free State summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FN13	81.97	18.03	78.05	21.95	64.38	35.62	1	0	1	1.00	0.75	1.00
FN21	78.19	21.81	85.21	14.79	78.44	21.56	2	0	2	1.00	0.81	1.00
FN22	82.86	17.14	83.55	16.45	74.15	25.85	1	0	1	1.00	0.80	1.00
FN25	76.02	23.98	84.65	15.35	72.35	27.65	1	0	1	1.00	0.78	1.00
FN28	90.14	9.86	93.06	6.94	80.80	19.20	9	0	9	1.00	0.88	1.00
FN29	86.64	13.36	93.38	6.62	85.80	14.20	1	3	4	0.25	0.89	–0.92
FN30	96.11	3.89	96.70	3.30	89.71	10.29	2	0	2	1.00	0.94	1.00
FN31	91.33	8.67	91.67	8.33	87.59	12.41	2	0	2	1.00	0.90	1.00
FN32	93.84	6.16	96.96	3.04	92.73	7.27	5	0	5	1.00	0.95	1.00
FN43	95.52	4.48	96.24	3.76	88.21	11.79	10	0	10	1.00	0.93	1.00
FN45	79.64	20.36	83.53	16.47	78.71	21.29	7	0	7	1.00	0.81	1.00
FN54	29.31	70.69	56.13	43.87	46.02	53.98	1	0	1	1.00	0.44	1.00
FN57	71.46	28.54	77.04	22.96	67.53	32.47	9	0	9	1.00	0.72	1.00
Overall	**80.89**	**19.11**	**85.62**	**14.38**	**77.27**	**22.73**	**94.44**	**5.56**	**54**	**0.94**	**0.81**	**0.59**

North-eastern Free State winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EV01	99.22	0.78	91.24	8.76	97.85	2.15	16	0	**16**	1.00	0.96	**1.00**
FN27	84.78	15.22	86.28	13.72	74.04	25.96	0	1	**1**	0.00	0.82	**–1.00**
FN28	90.14	9.86	93.06	6.94	80.80	19.20	2	0	**2**	1.00	0.88	**1.00**
FN58	46.52	53.48	63.36	36.48	53.43	46.57	5	0	**5**	1.00	0.54	**1.00**
Overall	**78.39**	**21.61**	**82.47**	**17.53**	**75.13**	**24.87**	**95.83**	**4.17**	**24**	**0.96**	**0.79**	**0.72**

Northern KwaZulu-Natal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD02	90.63	9.37	42.52	57.48	81.19	18.81	5	0	**5**	1.00	0.71	**1.00**
KD03	73.19	26.81	63.50	36.50	71.00	29.00	0	2	**2**	0.00	0.69	**–1.00**
KD08	73.77	26.23	47.10	52.90	65.28	34.72	5	0	**5**	1.00	0.62	**1.00**
KD09	62.50	37.50	44.62	55.38	56.86	43.14	1	1	**2**	0.50	0.55	**–0.09**
KD12	53.59	46.41	35.89	64.11	46.91	53.09	1	0	**1**	1.00	0.45	**1.00**
KN01	92.39	7.61	95.58	4.42	87.95	12.05	3	5	**8**	0.38	0.92	**–0.90**
KN03	72.35	27.65	81.62	18.38	65.49	34.51	5	0	**5**	1.00	0.73	**1.00**
KN08	90.15	9.85	88.17	11.83	86.16	13.84	9	1	**10**	0.90	0.88	**0.09**
KO01	83.35	16.65	62.28	37.72	69.53	30.47	1	0	**1**	1.00	0.72	**1.00**
KP01	61.57	38.43	43.70	56.30	48.86	51.14	4	0	**4**	1.00	0.51	**1.00**
KV01	64.93	35.07	42.89	57.10	58.82	41.18	25	0	**25**	1.00	0.56	**1.00**
KV04	99.06	0.94	93.26	6.74	80.09	19.91	2	0	**2**	1.00	0.91	**1.00**
Overall	**75.30**	**24.70**	**60.15**	**39.85**	**67.74**	**32.26**	**87.14**	**12.86**	**70**	**0.87**	**0.68**	**0.53**

Northern KwaZulu-Natal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
KD02	90.63	9.37	42.52	57.48	81.19	18.81	4	0	**4**	1.00	0.71	**1.00**
KD03	73.19	26.81	63.50	36.50	71.00	29.00	0	8	**8**	0.00	0.69	**–1.00**
KD09	62.50	37.50	44.62	55.38	56.86	43.14	2	2	**4**	0.50	0.55	**–0.09**
KL10	68.60	31.40	83.83	16.17	80.97	19.03	2	0	**2**	1.00	0.78	**1.00**
KN03	72.35	27.65	81.62	18.38	65.49	34.51	2	0	**2**	1.00	0.73	**1.00**
KN04	69.89	30.11	78.67	21.33	70.79	29.21	2	0	**2**	1.00	0.73	**1.00**
KN05	81.38	18.62	86.02	13.98	77.39	22.61	2	2	**4**	0.50	0.82	**–0.63**
KN08	90.15	9.85	88.17	11.83	86.16	13.84	1	0	**1**	1.00	0.88	**1.00**
KN09	90.76	9.24	92.84	7.16	58.78	41.22	1	0	**1**	1.00	0.81	**1.00**
KP01	61.57	38.43	43.70	56.30	48.86	51.14	0	1	**1**	0.00	0.51	**–1.00**
KV01	64.93	35.07	42.89	57.10	58.82	41.18	33	26	**59**	0.56	0.56	**0.01**
KV02	88.79	11.21	67.00	33.00	74.78	25.22	3	0	**3**	1.00	0.77	**1.00**
KV03	83.28	16.72	76.06	23.94	66.49	33.51	2	0	**2**	1.00	0.75	**1.00**
Overall	**76.68**	**23.32**	**66.60**	**33.40**	**68.61**	**31.39**	**58.06**	**41.94**	**93**	**0.58**	**0.71**	**–0.27**

Overberg summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
OV02	11.48	88.52	16.83	83.17	4.11	95.89	0	2	**2**	0.00	0.11	**–1.00**
OV03	35.26	64.74	40.32	59.68	30.17	69.83	1	16	**17**	0.06	0.35	**–0.79**
OV04	20.45	79.55	18.98	81.02	8.25	91.75	2	2	**4**	0.50	0.16	**0.68**
OV05	15.54	84.46	20.00	80.00	5.13	94.87	0	25	**25**	0.00	0.14	**–1.00**
OV06	19.50	80.50	21.56	78.44	7.50	92.50	5	44	**49**	0.10	0.16	**–0.26**
OV07	9.42	90.58	15.91	84.09	3.71	96.29	0	16	**16**	0.00	0.10	**–1.00**
OV08	18.08	81.92	12.90	87.10	5.38	94.62	11	32	**43**	0.26	0.12	**0.43**
OV09	6.59	93.41	12.79	87.21	3.28	96.72	0	11	**11**	0.00	0.08	**–1.00**
OV11	66.86	33.14	50.08	49.92	38.87	61.13	21	72	**93**	0.23	0.52	**–0.57**
OV12	49.73	50.26	30.61	69.39	23.04	76.96	10	190	**200**	0.05	0.34	**–0.82**
OV13	16.61	83.39	21.01	78.99	5.26	94.74	10	24	**34**	0.29	0.14	**0.43**
OV14	15.01	84.99	23.40	76.60	8.26	91.74	0	31	**31**	0.00	0.16	**–1.00**
OV15	10.40	89.60	14.02	85.98	3.75	96.25	1	7	**8**	0.13	0.09	**0.16**
OV16	10.66	89.34	11.11	88.89	4.85	95.15	0	31	**31**	0.00	0.09	**–1.00**
OV17	45.40	54.60	54.19	45.81	32.40	67.60	0	24	**24**	0.00	0.44	**–1.00**
OV19	12.12	87.88	16.26	83.74	3.95	96.05	0	21	**21**	0.00	0.11	**–1.00**
OV20	8.59	91.41	12.15	87.85	1.44	98.56	3	15	**18**	0.17	0.07	**0.43**
OV21	19.79	80.21	16.20	83.80	3.22	96.78	5	48	**53**	0.09	0.13	**–0.18**
OV22	27.77	72.23	21.32	78.68	9.95	90.05	0	17	**17**	0.00	0.20	**–1.00**
OV23	27.95	72.05	28.83	71.17	13.67	86.33	0	6	**6**	0.00	0.23	**–1.00**
OV24	67.05	32.95	47.99	52.01	36.26	63.74	20	200	**220**	0.09	0.50	**–0.82**
OV26	38.09	61.91	47.09	52.91	29.57	70.43	0	2	**2**	0.00	0.38	**–1.00**
OV27	44.97	55.03	48.35	51.65	34.19	65.81	11	12	**23**	0.48	0.43	**0.11**
OV28	60.37	39.63	48.95	51.05	36.56	63.44	2	4	**6**	0.33	0.49	**–0.31**
OV29	55.84	44.16	43.32	56.68	25.30	74.70	1	1	**2**	0.50	0.41	**0.17**
OV33	60.75	39.25	42.33	57.67	28.09	71.91	27	29	**56**	0.48	0.44	**0.09**
OV34	75.78	24.22	96.34	3.66	91.43	8.57	12	14	**26**	0.46	0.88	**–0.79**
OV35	33.42	66.58	42.21	57.79	32.00	68.00	0	2	**2**	0.00	0.36	**–1.00**
OV36	25.34	74.66	31.51	68.49	21.07	78.93	1	9	**10**	0.10	0.26	**–0.52**
OV37	39.58	60.42	52.64	47.36	35.96	64.04	0	2	**2**	0.00	0.43	**–1.00**
WK02	39.72	60.28	57.66	42.34	40.26	59.74	0	4	**4**	0.00	0.46	**–1.00**
Overall	**30.56**	**69.44**	**31.33**	**68.67**	**18.85**	**81.15**	**13.54**	**86.46**	**1056**	**0.14**	**0.27**	**–0.40**

	Overberg winter											
	NLC1994 % land area		**NLC2000 % land area**		**NLC2009 % land area**		**No. DBs**			**Jacobs index**		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
OV01	5.87	94.13	15.04	84.96	3.32	96.68	0	3	**3**	0.00	0.08	**–1.00**
OV02	11.48	88.52	16.83	83.17	4.11	95.89	0	3	**3**	0.00	0.11	**–1.00**
OV03	35.26	64.74	40.32	59.68	30.17	69.83	7	34	**41**	0.17	0.35	**–0.45**
OV04	20.45	79.55	18.98	81.02	8.25	91.75	2	14	**16**	0.13	0.16	**–0.14**
OV05	15.54	84.46	20.00	80.00	5.13	94.87	12	124	**136**	0.09	0.14	**–0.24**
OV06	19.50	80.50	21.56	78.44	7.50	92.50	17	349	**366**	0.05	0.16	**–0.60**
OV07	9.42	90.58	15.91	84.09	3.71	96.29	7	154	**161**	0.04	0.10	**–0.40**
OV08	18.08	81.92	12.90	87.10	5.38	94.62	9	319	**328**	0.03	0.12	**–0.66**
OV09	6.59	93.41	12.79	87.21	3.28	96.72	0	17	**17**	0.00	0.08	**–1.00**
OV10	2.27	97.73	8.38	91.62	1.83	98.17	0	24	**24**	0.00	0.04	**–1.00**
OV11	66.86	33.14	50.08	49.92	38.87	61.13	43	53	**96**	0.45	0.52	**–0.14**
OV12	49.73	50.26	30.61	69.39	23.04	76.96	52	203	**255**	0.20	0.34	**–0.34**
OV13	16.61	83.39	21.01	78.99	5.26	94.74	70	389	**459**	0.15	0.14	**0.04**
OV14	15.01	84.99	23.40	76.60	8.26	91.74	6	169	**175**	0.03	0.16	**–0.68**
OV15	10.40	89.60	14.02	85.98	3.75	96.25	21	58	**79**	0.27	0.09	**0.55**
OV16	10.66	89.34	11.11	88.89	4.85	95.15	31	306	**337**	0.09	0.09	**0.02**
OV17	45.40	54.60	54.19	45.81	32.40	67.60	5	49	**54**	0.09	0.44	**–0.77**
OV18	31.88	68.12	28.95	71.05	16.91	83.09	1	15	**16**	0.06	0.26	**–0.68**
OV19	12.12	87.88	16.26	83.74	3.95	96.05	2	79	**81**	0.02	0.11	**–0.65**
OV20	8.59	91.41	12.15	87.85	1.44	98.56	5	104	**109**	0.05	0.07	**–0.25**
OV21	19.79	80.21	16.20	83.80	3.22	96.78	32	115	**147**	0.22	0.13	**0.30**
OV22	27.77	72.23	21.32	78.68	9.95	90.05	1	42	**43**	0.02	0.20	**–0.82**
OV23	27.95	72.05	28.83	71.17	13.67	86.33	12	0	**12**	1.00	0.23	**1.00**
OV24	67.05	32.95	47.99	52.01	36.26	63.74	19	195	**214**	0.09	0.50	**–0.83**
OV25	30.18	69.82	40.58	59.42	25.67	74.33	0	4	**4**	0.00	0.32	**–1.00**
OV27	44.97	55.03	48.35	51.65	34.19	65.81	1	46	**47**	0.02	0.43	**–0.94**
OV28	60.37	39.63	48.95	51.05	36.56	63.44	0	5	**5**	0.00	0.49	**–1.00**
OV29	55.84	44.16	43.32	56.68	25.30	74.70	0	1	**1**	0.00	0.41	**–1.00**
OV31	15.11	84.89	22.14	77.86	4.60	95.40	0	22	**22**	0.00	0.14	**–1.00**
OV33	60.75	39.25	42.33	57.67	28.09	71.91	52	60	**112**	0.46	0.44	**0.05**
OV34	75.78	24.22	96.34	3.66	91.43	8.57	5	23	**28**	0.18	0.88	**–0.94**
OV35	33.42	66.58	42.21	57.79	32.00	68.00	0	6	**6**	0.00	0.36	**–1.00**
OV36	25.34	74.66	31.51	68.49	21.07	78.93	0	13	**13**	0.00	0.26	**–1.00**
OV37	39.58	60.42	52.64	47.36	35.96	64.04	1	13	**14**	0.07	0.43	**–0.81**
Overall	**28.37**	**71.63**	**29.29**	**70.71**	**17.06**	**82.94**	**12.06**	**87.94**	**3424**	**0.12**	**0.25**	**–0.41**

Southern KwaZulu-Natal summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
KC01	66.24	33.76	48.49	51.51	57.89	42.11	18	1	**19**	0.95	0.58	**0.86**
KG02	80.90	19.10	67.56	32.44	66.51	33.49	8	14	**22**	0.36	0.72	**–0.63**
KG03	75.42	24.58	72.67	27.33	59.88	40.12	3	0	**3**	1.00	0.69	**1.00**
KG04	74.49	25.51	82.50	17.50	62.77	37.23	17	2	**19**	0.89	0.73	**0.51**
KG05	64.23	35.77	69.75	30.25	55.16	44.84	12	0	**12**	1.00	0.63	**1.00**
KG06	82.31	17.69	80.47	19.53	66.51	33.49	19	4	**23**	0.83	0.76	**0.19**
KG07	70.43	29.57	83.46	16.54	67.07	32.93	16	0	**16**	1.00	0.74	**1.00**
KG08	84.60	15.40	81.40	18.60	73.09	26.91	4	8	**12**	0.33	0.80	**–0.77**
KG09	61.23	38.77	62.12	37.88	50.34	49.66	23	0	**23**	1.00	0.58	**1.00**
KG10	71.99	28.01	81.91	18.09	58.23	41.77	2	0	**2**	1.00	0.71	**1.00**
KM01	71.51	28.49	66.40	33.60	57.66	42.34	17	0	**17**	1.00	0.65	**1.00**
KM02	64.16	35.84	57.70	42.30	57.78	42.22	8	0	**8**	1.00	0.60	**1.00**
KM03	56.99	43.01	60.07	39.93	53.77	46.23	16	1	**17**	0.94	0.57	**0.85**
KM04	86.92	13.08	67.99	32.01	77.05	22.95	1	0	**1**	1.00	0.77	**1.00**
KM05	55.31	44.69	50.98	49.02	52.13	47.87	5	0	**5**	1.00	0.53	**1.00**
KM07	89.76	10.24	75.12	24.88	87.78	12.22	5	0	**5**	1.00	0.84	**1.00**
KM08	30.07	69.93	24.92	75.08	24.76	75.24	2	0	**2**	1.00	0.27	**1.00**
KU01	66.95	33.05	66.23	33.77	62.61	37.39	21	13	**34**	0.62	0.65	**–0.08**
KU02	78.07	21.93	74.09	25.91	69.83	30.17	27	11	**38**	0.71	0.74	**–0.07**
KU03	82.84	17.16	82.17	17.83	70.61	29.39	6	0	**6**	1.00	0.79	**1.00**
Overall	**70.41**	**29.59**	**67.72**	**32.28**	**61.64**	**38.36**	**80.99**	**19.01**	**284**	**0.81**	**0.67**	**0.36**

Southern KwaZulu-Natal winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
KC01	66.24	33.76	48.49	51.51	57.89	42.11	45	38	**83**	0.54	0.58	**–0.07**
KG01	66.86	33.14	71.97	28.03	59.74	40.26	0	10	**10**	0.00	0.66	**–1.00**
KG02	80.90	19.10	67.56	32.44	66.51	33.49	18	52	**70**	0.26	0.72	**–0.76**
KG03	75.42	24.58	72.67	27.33	59.88	40.12	18	14	**32**	0.56	0.69	**–0.27**
KG04	74.49	25.51	82.50	17.50	62.77	37.23	34	2	**36**	0.94	0.73	**0.72**
KG05	64.23	35.77	69.75	30.25	55.16	44.84	7	1	**8**	0.88	0.63	**0.61**
KG06	82.31	17.69	80.47	19.53	66.51	33.49	72	18	**90**	0.80	0.76	**0.10**
KG07	70.43	29.57	83.46	16.54	67.07	32.93	26	16	**42**	0.62	0.74	**–0.26**
KG08	84.60	15.40	81.40	18.60	73.09	26.91	1	0	**1**	1.00	0.80	**1.00**
KG09	61.23	38.77	62.12	37.88	50.34	49.66	44	1	**45**	0.98	0.58	**0.94**
KG10	71.99	28.01	81.91	18.09	58.23	41.77	6	5	**11**	0.55	0.71	**–0.34**
KG11	68.65	31.35	77.28	22.72	62.88	37.12	0	5	**5**	0.00	0.70	**–1.00**
KM01	71.51	28.49	66.40	33.60	57.66	42.34	5	9	**14**	0.36	0.65	**–0.54**
KM02	64.16	35.84	57.70	42.30	57.78	42.22	1	7	**8**	0.13	0.60	**–0.83**
KM03	56.99	43.01	60.07	39.93	53.77	46.23	11	1	**12**	0.92	0.57	**0.79**
KM05	55.31	44.69	50.98	49.02	52.13	47.87	3	6	**9**	0.33	0.53	**–0.38**
KM06	60.68	39.32	51.65	48.35	53.78	46.22	0	5	**5**	0.00	0.55	**–1.00**
KM07	89.76	10.24	75.12	24.88	87.78	12.22	4	0	**4**	1.00	0.84	**1.00**
KM08	30.07	69.93	24.92	75.08	24.76	75.24	2	9	**11**	0.18	0.27	**–0.24**
KU01	66.95	33.05	66.23	33.77	62.61	37.39	14	55	**69**	0.20	0.65	**–0.76**
KU02	78.07	21.93	74.09	25.91	69.83	30.17	23	13	**36**	0.64	0.74	**–0.23**
KU03	82.84	17.16	82.17	17.83	70.61	29.39	0	2	**2**	0.00	0.79	**–1.00**
Overall	**68.99**	**31.01**	**67.07**	**32.93**	**60.56**	**39.44**	**55.39**	**44.61**	**603**	**0.55**	**0.66**	**–0.21**

Steenkampsberg summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MS01	90.35	9.65	91.55	8.45	90.87	9.13	2	0	**2**	1.00	0.91	**1.00**
MS02	87.69	12.31	93.88	6.12	93.06	6.94	2	0	**2**	1.00	0.92	**1.00**
MS05	90.34	9.66	84.28	15.72	83.98	16.02	1	0	**1**	1.00	0.86	**1.00**
MS06	82.19	17.81	84.64	15.36	83.39	16.61	19	0	**19**	1.00	0.83	**1.00**
MS09	84.09	15.91	88.12	11.88	80.83	19.17	1	0	**1**	1.00	0.84	**1.00**
MS13	74.62	25.38	78.82	21.18	78.20	21.80	1	0	**1**	1.00	0.77	**1.00**
Overall	**84.53**	**15.47**	**86.64**	**13.36**	**84.84**	**15.16**	**100.00**	**0.00**	**26**	**1.00**	**0.85**	**1.00**

Steenkampsberg winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MS01	90.35	9.65	91.55	8.45	90.87	9.13	3	0	**3**	1.00	0.91	**1.00**
MS07	93.50	6.50	92.62	7.38	90.89	9.11	0	3	**3**	0.00	0.92	**–1.00**
Overall	**91.98**	**8.02**	**92.11**	**7.89**	**90.88**	**9.12**	**50.00**	**50.00**	**6**	**0.50**	**0.92**	**–0.83**

Wakkerstroom summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MW03	90.38	9.62	92.84	7.16	88.01	11.99	7	0	**7**	1.00	0.90	**1.00**
MW07	77.81	22.19	88.44	11.56	80.17	19.83	2	0	**2**	1.00	0.82	**1.00**
MW09	82.99	17.01	86.58	13.42	83.48	16.52	6	0	**6**	1.00	0.84	**1.00**
Overall	**83.58**	**16.42**	**89.01**	**10.99**	**83.80**	**16.20**	**100.00**	**0.00**	**15**	**1.00**	**0.85**	**1.00**

Wakkerstroom winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. DBs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MW01	76.70	23.30	51.24	48.76	59.92	40.08	1	0	**1**	1.00	0.63	**1.00**
MW02	74.09	25.91	76.35	23.65	74.89	25.11	6	4	**10**	0.60	0.75	**–0.34**
MW06	72.17	27.83	85.12	14.88	70.39	29.61	18	1	**19**	0.95	0.76	**0.70**
MW07	77.81	22.19	88.44	11.56	80.17	19.83	2	0	**2**	1.00	0.82	**1.00**
MW08	86.45	13.55	81.53	18.47	81.53	18.47	0	3	**3**	0.00	0.83	**–1.00**
MW09	82.99	17.01	86.58	13.42	83.48	16.52	1	0	**1**	1.00	0.84	**1.00**
Overall	**79.19**	**20.81**	**79.22**	**20.78**	**76.23**	**23.77**	**77.78**	**22.22**	**36**	**0.78**	**0.78**	**–0.01**

Table A3.3: Four sets of unequal weights used to produce the national population indices for the Denham's Bustard. (The fifth set used equal weighting, i.e. a weight of 0.20 for each precinct.) The area of a precinct was defined as that of all the quarter-degree grid cells the routes of the precinct entered. This was also the area for which reporting rates (RR, defined as the percentage of atlas lists from a precinct which reported Denham's Bustards) were extracted. Reporting rates from SABAP1 were used (Harrison et al. 1997). For the "Area*Griffioen RR" weights, the conversion proposed by Griffioen (2001) was applied to the reporting rates (see text) before multiplying them by the precinct areas.

	Area		RR		Area*RR		Area*Griffioen RR	
Precinct	**km^2**	**Weights**	**%**	**Weights**	**km^2*%**	**Weights**	**km^2*(–*ln*(1–RR))**	**Weights**
E Cape Coastal	6000.30	0.07	10.75	0.17	64473.83	0.06	682.08	0.06
Little Karoo	16713.02	0.21	2.87	0.04	47996.36	0.04	486.99	0.04
NE Eastern Cape	24196.92	0.30	19.50	0.30	471763.91	0.42	5247.68	0.43
Overberg	17706.28	0.22	17.68	0.27	313098.82	0.28	3445.49	0.28
S KwaZulu-Natal	15870.03	0.20	14.23	0.22	225793.10	0.20	2435.63	0.20

Table A3.4: National population index values calculated for the Denham's Bustard using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weights given in Table A3.3 and summing the results for each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

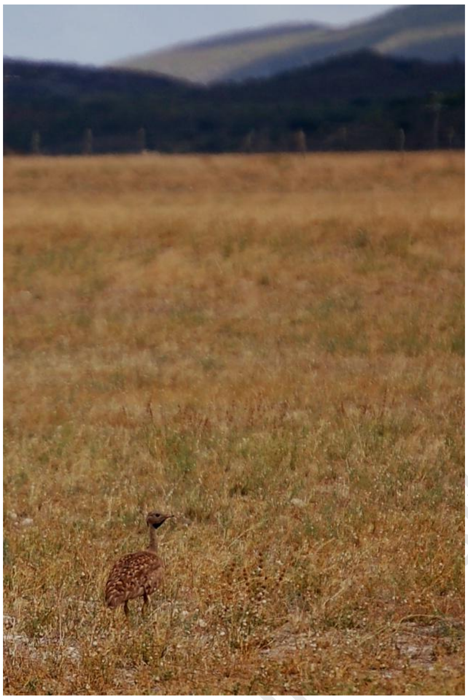
Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1994	1.41	1.43	1.12	1.02	1.01
1995	1.40	1.42	1.10	1.00	0.99
1996	1.51	1.57	1.27	1.23	1.23
1997	1.43	1.46	1.14	1.06	1.04
1998	1.44	1.47	1.17	1.09	1.08
1999	1.42	1.44	1.13	1.04	1.03
2000	0.94	1.35	0.76	1.11	1.11
2001	0.75	0.79	0.73	0.75	0.75
2002	0.56	0.68	0.63	0.79	0.80
2003	0.79	0.91	0.82	0.97	0.98
2004	0.89	1.02	0.74	0.79	0.78
2005	1.08	1.07	1.00	0.97	0.96
2006	0.64	0.79	0.66	0.83	0.84
2007	1.25	1.28	1.48	1.60	1.62
2008	0.81	0.74	0.97	0.98	0.99
2009	0.61	0.62	0.72	0.78	0.78
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1993	0.54	0.66	0.62	0.74	0.74
1994	0.50	0.60	0.57	0.67	0.67
1995	0.59	0.74	0.69	0.84	0.85
1996	0.51	0.62	0.59	0.69	0.70
1997	0.49	0.59	0.55	0.65	0.65
1998	0.43	0.50	0.48	0.55	0.55
1999	0.42	0.50	0.47	0.55	0.56
2000	0.78	0.78	0.84	0.87	0.87
2001	0.65	0.69	0.70	0.75	0.76
2002	0.52	0.51	0.50	0.47	0.46
2003	1.02	1.13	0.85	0.87	0.86
2004	0.69	0.71	0.68	0.69	0.69
2005	0.75	0.80	0.74	0.79	0.79
2006	0.91	0.92	0.94	0.95	0.95
2007	0.77	0.64	0.70	0.55	0.55
2008	0.76	0.76	0.80	0.81	0.81
2009	0.79	0.87	0.81	0.89	0.89
2010	1.00	1.00	1.00	1.00	1.00

Chapter 6

Population trends and environmental challenges of three South African korhaans: Blue Korhaan *Eupodotis caerulescens*, Karoo Korhaan *Eupodotis vigorsii*, Northern Black Korhaan *Afrotis afraoides*



It is also a well known fact that the Korhaan are an infallible wind predictor. If they start their call in chorus early in the morning, the wind will start blowing within the course of the next few hours. The earlier they start and the bigger the chorus, the greater the storm. It is not so difficult to understand how they know, if one is a student of nature, but it would be interesting to know why, and for whose benefit they give such unmistakable warning?

~ WF Quinton, 1948

Abstract

Bustards in general are poorly known and many species are threatened. In light of this and the availability of suitable long-term data, the population status of three southern African endemic korhaans (small bustards) was assessed. The Blue Korhaan *Eupodotis caerulescens* is endemic to South Africa and has a small range in the Grassland and grassy Nama Karoo biomes. The Karoo Korhaan *E. vigorsii* is restricted to the Nama and Succulent Karoo biomes, except where it has expanded its range into the Fynbos biome, probably since agricultural cultivation began in this area. The Northern Black Korhaan *Afrotis afraoides* is common throughout much of its large range, in the Grassland, Nama Karoo and Savanna biomes. Population trends produced using Coordinated Avifaunal Roadcounts (CAR) project data for 1995–2010 were stable or slightly increasing overall for all species. Comparison of data from the first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992, and SABAP2, 2007–) suggested that the Blue Korhaan population had decreased in the north-east of its range but remained stable elsewhere. Karoo Korhaan reporting rates remained stable but the species' range was poorly covered by SABAP2. Northern Black Korhaan reporting rates increased in the Free State but decreased slightly elsewhere. CAR habitat use data showed that Northern Black Korhaans select against transformed habitats, Karoo Korhaans use them in the Western Cape, and Blue Korhaans use them rarely in summer but more frequently in winter. National population indices produced using CAR and SABAP data suggested that the populations of all three species increased slightly or remained stable, but only the Blue Korhaan population was well covered by CAR.

Introduction

Of South Africa's 10 bustard species, the best known and most studied are the three large bustards (Kori Bustard *Ardeotis kori*, Denham's Bustard *Neotis denhami* and Ludwig's Bustard *N. ludwigii*), although like all bustards they are still comparatively poorly studied. Of the seven smaller species, of which six are known locally as korhaans, four are well covered by data from two citizen science projects, the Coordinated Avifaunal Roadcounts (CAR) project (Chapter 1, Young et al. 2003) and the two Southern African Bird Atlas Projects (SABAP1 and SABAP2) (Chapter 1, Harrison et al. 1997). Analyses of these data enable us to increase our knowledge of the status and challenges faced by these species. One, the Southern Black Korhaan *Afrotis afra*, has already been dealt with in this thesis (Chapter 3). This study, therefore, focuses on the remaining three: Blue Korhaan *Eupodotis caerulescens*, Karoo Korhaan *E. vigorsii* and Northern Black Korhaan *A. afraoides*.

These three species are endemic to southern Africa, and the Blue Korhaan to South Africa (although it occurs marginally in Lesotho) (Allan 2005a, 2005b, 2005c). They are similar in size, all measuring 50–60 cm in length, although the Northern Black Korhaan is approximately half the weight of the other two species. Blue and Karoo Korhaans belong to the white-bellied group of small bustards which prefer open habitats, and the two species are thought to be closely related (Kemp and Tarboton 1976, Collar 1996). They are similar in several respects, but their habitat preference is quite different: Karoo Korhaans, as the name suggests, prefer arid open low scrub karoo habitats (although not those dominated by succulents), while Blue Korhaans are found in short, sparse grassland and in the eastern grassy extremities of the Nama Karoo biome (Figures 1a and b) (Kemp and Tarboton 1976, Allan 2005a, 2005b, Moreira 2006). The Karoo Korhaan also occurs in the Overberg region of the Fynbos biome in the Western Cape (Figures 1a and c). It is rarely observed in natural vegetation there and instead makes use of open agricultural habitats (Uys 1981, Allan 2005b). This has led to the hypothesis that the species expanded its range into that region after humans began to practise agriculture there, although the species has been there since at least the 1860s (Allan 2005b). Both the Karoo and Blue Korhaans are sedentary and territorial, and are most frequently seen in pairs or small groups (Maclean et al. 1983, Hockey and Boobyer 1994, Moreira 2006). They both have cryptic plumage and can be difficult to see, but they have far-carrying territorial calls (Allan 2005a, 2005b) and often give their presence away by calling. They call mainly in the early morning and in the evening, but sometimes call throughout the day in cool, overcast weather (SDH, pers. obs).

Northern Black Korhaans belong to the black-bellied small bustards which prefer less open habitats (Kemp and Tarboton 1976, Collar 1996). Until 1994 it was considered conspecific with the Southern Black Korhaan, but was split from it on the basis of genetic, behavioural and phenotypic traits, habitat preference and distribution (Chapter 3, Crowe et al. 1994). It prefers more open habitats than the other black-bellied bustards; these include arid savanna, arid grassland, and grassy karoo (Figures 1a and d). These habitats are dominated by grass with at most small shrubs or scattered trees, and receive predominantly summer rainfall (Crowe et al. 1994). The Northern Black Korhaan is never seen in groups unless a specific interaction is taking place (either courtship or a dispute between competing males; Kemp and Tarboton 1976, SDH pers.

obs). Males display frequently and vigorously all year round, although more frequently during summer, and throughout the day but more frequently in the early morning and late afternoon (de Swardt 1992, Allan 2005c). The display involves calling raucously from a prominent point such as a termite mound and from time to time performing an aerial display, which consists of flying in circles above the display site, with exaggerated wing-beats, while calling, and then descending to the ground slowly with wings fluttering and yellow legs dangling (de Swardt 1992, Allan 2005c). Males are also boldly marked, with black heads, necks and bellies and contrasting white cheek patches, so they are easy to see and identify. Females, however, are cryptically coloured and secretive, and the ratio of females to males observed is therefore low (Crowe et al. 1994). The species is primarily sedentary but undertakes local movements and quickly colonises new areas in response to changing local conditions (Allan 1997a).

Neither Karoo nor Northern Black Korhaans are thought to be threatened, and Karoo Korhaans may even have benefitted from human activities to some extent, since they feed extensively on plant species typical of disturbed areas (Boobyer and Hockey 1994, Allan 2005b, 2005c, BirdLife International 2012). In fact, Boobyer (1994) cites Burchell's 1822 book on his travels in southern Africa as saying the Karoo Korhaan was extremely rare in the early 19th century; "during extensive and lengthy travels in the karoo… [he] encountered this species only once". It is now described as "common" (Collar 1996, Sinclair et al. 2011), and has almost certainly increased significantly in abundance since the karoo region was settled by Europeans and widespread pastoralism became established there (Boobyer and Hockey 1994). The Blue Korhaan is listed as Near-threatened on the IUCN Red List even though it is thought that the population is stable (BirdLife International 2012). It is suspected to have decreased in abundance in the east of its range because of the dense human population, afforestation and intensive agriculture, however, and is thought to be at risk of further and possibly rapid decline if such habitat loss continues (Allan 2005a, BirdLife International 2012).

This study aims to use the data from the CAR project, SABAP1 and SABAP2 to determine the current status of these three korhaans in South Africa, using methods developed in an earlier study (Chapter 3). CAR project data are used to assess population trends of the species in as many areas as possible, and to examine habitat use and selection in these areas to gain a better understanding of the needs of and threats to these species. SABAP data are compared numerically to further examine the changes in status of the species between the two data collection periods. Finally, CAR data and SABAP data are combined to produce national population indices for each species.

Methods

CAR project

Data collection

The CAR project was initiated in 1993 in the Overberg region of the Western Cape, and expanded to cover much of the south-eastern half of South Africa over the following eight years (Chapter 1, Young et al. 2003). Volunteers undertook surveys of defined "routes", with a target distance of about 60 km each. The project initially only surveyed Blue Cranes *Anthropoides paradiseus* and Denham's Bustards *Neotis denhami*, but korhaans were added to the list of species surveyed in either 1997 or 1998 in most precincts; Karoo Korhaans had been included in the Eastern Karoo precinct in 1995. The routes, which were primarily through agricultural areas, were surveyed twice a year, once in summer and once in winter. Korhaans observed along the route were counted according to a strict protocol, and relevant variables were collected (Chapter 1). Korhaans are medium-sized birds and therefore are probably not visible from more than 1 000 m away when using binoculars, although the distance visible from the road is greater in many places. We thus interpret the counts as an index of the number of korhaans within a transect 2 000 m wide, symmetrically placed on either side of the route. However, CAR observers did not record the distance from the road of each sighting, precluding the application of "distance sampling" (Buckland et al. 1993) to the data; it was therefore not possible to transform the counts into densities. Thus one of the constraints imposed by the data collection protocol is that the results need to be expressed in linear units; the convenient metric is birds per 100 km.

Analysis – population trends

The CAR routes were separated into "precincts" — ecologically distinct areas with similar vegetation and climate characteristics — based on the precincts used in the Mazda CAR report (Young et al. 2003) and by examining vegetation maps (Mucina and Rutherford 2006) of areas surrounding any new routes. Count data for each precinct were analysed separately. Only precincts with sufficient data for a meaningful analysis were used; the estimated total number of birds for entire precinct and period both counted and imputed (see Chapter 3 for precise definition) was greater than 100. Summer and winter totals were analysed separately.

The Underhill index (Underhill and Prŷs-Jones 1994) was applied to the data (Chapter 3). The resulting annual precinct totals were analysed in the same way as those for the Southern Black Korhaan (Chapter 3).

Analysis – habitat use

Habitat use data collected by CAR project participants were extracted and summarised. All of the available data were used, including the few observations made before the species were officially included in the project, because this did not violate any assumptions (as it would have done for the trend analysis). Additional precincts were included which did not have sufficient data for the population trend analysis, but did for the habitat selection analysis. Precincts were included if the number of routes on which birds were observed in at least one of the seasons was five or more.

Habitat selection and habitat use were analysed as for the Southern Black Korhaan (Chapter 3), with the following exception. Habitat availability for the Karoo Korhaan in the Eastern Karoo precinct was calculated using the 1994 National Land-Cover map (NLC1994) (Thompson 1999) in addition to NLC2000 and NLC2009 (CSIR and ARC 2005, SANBI 2009). The earlier map was included so as to give a more accurate representation of habitat availability for the entire period over which Karoo Korhaans were surveyed in this precinct (1995–2010).

SABAP

Data collection

The first and second Southern African Bird Atlas Projects (SABAP1 and SABAP2) represent distinct iterations of southern Africa's largest-scale bird monitoring project (Harrison et al. 2008). The protocol used for SABAP1 (1987–1992) is described in Chapter 1 and in Harrison and Underhill (1997), and for SABAP2 (2007–) on the project's website (http://sabap2.adu.org.za/), and a summary is provided in Chapter 1.

SABAP comparison map

We used a visual method, termed a SABAP comparison map, to examine the changes in reporting rates for the three species from the first atlas project to the second, using all data submitted up until 8 February 2012. A statistic which takes into account the difference in reporting rates and sample sizes of checklists was calculated for each atlas quarter-degree grid cell (QDGC) to evaluate the importance of these changes (Chapter 3).

National population trend index

The status of the portion of the population of each of the species that was covered by the CAR project was modelled using the method developed for the Southern Black Korhaan (Chapter 3) and Blue Crane (Chapter 4). The proportion of each species' range covered by the CAR project, and the importance of this area in terms of the whole population, was assessed.

Results

CAR project

Population trends

Precincts with sufficient Blue Korhaan data to be included in this analysis were Eastern Karoo, Mpumalanga, North-eastern Eastern Cape, North-eastern Free State, North-western Free State, Southern Free State and Wakkerstroom. For the Karoo Korhaan the precincts included were Beaufort West, Eastern Cape Karoo, Eastern Karoo and Overberg, and for the Northern Black Korhaan the Eastern Cape Karoo, Eastern Karoo, North-eastern Free State, North-western Free State and Southern Free State precincts (Figure 1 in Chapter 1). The number of years of data varied between eight and 15, and the number of routes per precinct varied between two and 78, with a median of 20 (Table 1). To ensure that the percentage of the overall total imputed in each analysis was less than 25%, the data were adjusted in various ways (Table 2).

Blue Korhaans decreased in abundance in the Eastern Karoo precinct and increased in the Mpumalanga precinct and the three Free State precincts (Figure 2a). Karoo Korhaan populations showed increasing trends in the Beaufort West and the Eastern Cape Karoo precincts in the winter analyses and in the Overberg for both summer and winter (Figure 2c). Northern Black Korhaans showed a decreasing trend in the Eastern Cape Karoo, and increasing trends in the Eastern Karoo and North-eastern Free State in summer only and in the North-western Free State and Southern Free State in both seasons (Figure 2d).

In general trends in abundance were weak, with $R^2 > 0.50$ in only five analyses (Appendix 4, Table A4.1). Average rates of change in Blue Korhaan totals were –6% per year for summer and –13% for winter in the Eastern Karoo precinct, and for precincts showing clear increasing trends rates of increase ranged from 2–3% per year (summer and winter rates respectively) for the Southern Free State to 13–16% per year for the North-western Free State. However in the North-western Free State the rate of population increase slowed, with inflection points at 2002–03 for winter and 2005–06 for the summer trend, although the rate of change in the winter trend once again began to increase in 2008–09. Karoo Korhaan totals increased at average rates of between 1–3% per year (Eastern Cape Karoo) and 3–8% per year (Eastern Karoo). Northern Black Korhaan totals decreased by an average of 2% per year in both seasons in the Eastern Cape Karoo precinct, but increased by from 4% per year (North-western Free State) to 21% per year (Eastern Karoo, summer only) in the remaining four precincts. North-eastern Free State summer totals increased by c. 20% per year in 2001–03, but by 2006 had stabilised; winter totals, however, were variable but approximately stable for the entire period.

The degree of variability in totals was lower for these species than for other species populations analysed in this way (Chapters 3, 4 and 5), and coefficients of variation were below 50% in the majority of analyses, exceeding this value in only seven cases out of 31 (Appendix 4, Table A4.1).

Blue Korhaans had the smallest densities of the three species, with means ranging from 1.1 birds/100 km (SD 0.7) in the North-western Free State precinct to 10.0 birds/100 km (SD 2.7) in the Southern Free State, exceeding 6 birds/100 km only in the latter precinct and the North-eastern Eastern Cape. Means were larger for winter surveys in all seven precincts, but the degree of difference varied with precinct. Winter densities were more than double those for summer in the North-eastern Free State, Mpumalanga and Wakkerstroom precincts (Mpumalanga precinct summer densities are not presented here because they did not meet the criteria for inclusion, but the mean was 1.5 birds/100 km), were close to double in the Southern Free State, and were c. 20% larger in the North-eastern Eastern Cape. In the Eastern Karoo and North-western Free State totals were only slightly larger in winter. The North-western Free State precinct was the only one analysed with mean densities of less than 2 birds/100 km (Appendix 4, Table A4.1a).

Karoo Korhaans had similar densities to Blue Korhaans in three precincts, but their densities were an order of magnitude larger in the Beaufort West precinct. Means ranged from 1.2 birds/100 km (SD 0.5) in the Overberg precinct to 33.3 birds/100 km (SD 15.0) in Beaufort West. Means of totals were larger for winter in three precincts, but smaller in the Eastern Karoo. Winter totals were approximately double those for summer in the Overberg and Eastern Cape Karoo precincts, approximately two-thirds that for summer in the Eastern Karoo, and c. 20% greater than the summer total in the Beaufort West precinct. The degree of variation in totals was similar for all analyses for this species, with CV values between 32% and 49% (Appendix 4, Table A4.1b).

Northern Black Korhaans were the most abundant of the three species. In the North-eastern Free State and Eastern Cape Karoo precincts they were recorded in similar numbers to the other two species, but in the remaining three precincts their densities ranged from 13.2 birds/100 km (SD 6.1; Eastern Karoo winter) to 43.4 birds/100 km (SD 16.0; North-western Free State summer). Means of totals for winter were smaller than those for summer in all cases; winter means were slightly more than half summer means in all precincts except the Eastern Cape Karoo, where it was less than half of that for summer. Variation was similar for all analyses for this species, ranging between 26% and 47%, except for the Eastern Karoo summer analysis, for which it was 61.9% (Appendix 4, Table A4.1c).

Habitat use

Additional precincts that were included in this analysis were Eastern Cape Coastal for the Blue Korhaan, Little Karoo and Southern Free State for the Karoo Korhaan, and Gauteng for the Northern Black Korhaan (Figure 1 in Chapter 1). The Beaufort West precinct was included in the Eastern Cape Karoo precinct for the Karoo Korhaan habitat selection analysis, because a large number of birds was seen in this precinct, which represents valuable data, but it consists of only two routes and so could not be analysed on its own. For the habitat use analysis, however, the Beaufort West precinct was treated as a separate precinct.

Blue Korhaans exhibited the highest levels of preference for transformed habitats of the three species, and Northern Black Korhaans the lowest (Table 3; Appendix 4, Table A4.2). The former species selected transformed land preferentially in both seasons in the Eastern Cape Karoo, Eastern Karoo and North-eastern Eastern Cape precincts (in terms of overall numbers but not numbers of routes on which a preference was shown). They also preferred transformed land in winter but not summer in the North-eastern Free State, Southern Free State and Wakkerstroom precincts, and Wakkerstroom was the only one of these for which the preference was expressed in terms of the number of routes as well as in terms of overall numbers. Karoo Korhaans showed a preference for transformed habitats in summer only in the Eastern Karoo, Little Karoo and Southern Free State precincts, and in the Overberg they showed a weak preference for transformed habitats in summer and were close to neutral in winter. Northern Black Korhaans showed no preference for transformed habitats except for a very slight preference in terms of overall numbers in the Eastern Cape Karoo precinct in winter, and in Gauteng their preference for natural habitats was significantly weaker in winter.

In terms of habitat use, the majority of Blue Korhaans were seen in natural habitats or at water in all precincts and seasons except Wakkerstroom in winter, where just over 50% of birds were seen in transformed habitats, and in the North-eastern Eastern Cape just under 50% of birds were in transformed habitats (Figure 3). In summer the only transformed habitats of importance (more than 10% of birds were seen in them) were crops in the Eastern Cape Karoo, and pastures in the Eastern Cape Karoo, Mpumalanga and North-eastern Eastern Cape precincts. In winter the most popular transformed habitats were pastures in the Eastern Cape Karoo and North-eastern Eastern Cape precincts, crop stubbles in the Mpumalanga, North-eastern Free State and Wakkerstroom precincts, crops in the North-eastern Eastern Cape and fallow land in Mpumalanga.

More than 95% of Karoo Korhaans were seen in natural habitats or at water in both seasons in the Beaufort West, Eastern Cape Karoo and Eastern Karoo precincts, and in the Southern Free State in winter (Figure 4). In the latter precinct in summer 84% of birds observed were in natural habitats or at water, and the remaining birds were in ploughed or fallow land or crop stubble fields. In the Little Karoo 52% of birds were in natural habitats in summer, and the remaining birds were in fallow land, crop stubbles and crop fields. In winter 11% of birds were in crop fields, and the remainder were in natural habitats. The majority of Karoo Korhaans in the Overberg were seen in transformed habitats; only 9% of birds were in natural habitats in summer, and 13% in winter. Other habitats used were fallow land, crop stubble fields, pastures, crop fields and ploughed land.

More than 94% of Northern Black Korhaans were seen in natural habitats or at water in all precincts in summer, and in the Eastern Karoo, North-western Free State and Southern Free State precincts in winter. In the Eastern Cape Karoo and North-eastern Free State more than 88% of birds were seen in natural habitats in winter, and the only other habitat of any importance was fallow land in the Eastern Cape Karoo precinct. In the Gauteng precinct in winter, 62% of birds were in natural habitats, and the remaining birds were seen in burnt land, pasture, stubble fields and crop fields.

SABAP

SABAP comparison maps

Reporting rates for the Blue Korhaan decreased in most of the north-eastern third of its range (Figure 6a), but were more stable in the rest of the range. Of the 144 QDGCs in the north-eastern third of the range, 101 had decreased reporting rates (23 red, 20 orange and 58 yellow), while 43 had increased reporting rates (eight blue, 11 dark green and 24 light green). In the remainder of the range 123 QDGCs had decreased reporting rates (12 red, 18 orange and 93 yellow) while 102 had increased reporting rates (12 blue, 17 dark green and 73 light green). There were also 16 QDGCs which had not yet been visited for SABAP2 in this part of the range (pink QDGCs). There was a contiguous block of 20 QDGCs in which reporting rates had significantly decreased around the Free State/KwaZulu-Natal/Mpumalanga border (Figure 6a).

Karoo Korhaan reporting rates were approximately stable or decreased slightly overall in the Eastern and Western Cape parts of the species' range (Figure 6b). Of the 194 QDGCs in these provinces, 110 showed decreased reporting rates (six red, 11 orange and 93 yellow), 77 had increased reporting rates (six blue, 19 dark green and 52 light green) and seven had not yet been visited for SABAP2. Much of the Northern Cape part of the range had not yet been covered by 8 February 2012, the date of map extraction. The only contiguous areas of significantly decreased reporting rates were in the Beaufort West area in the north-eastern Western Cape.

Reporting rates for the Northern Black Korhaan increased overall in the Free State and were stable or decreased somewhat in the North West and Limpopo provinces (Figure 6c). Of the 189 QDGCs in the Free State, reporting rates increased in 142 (39 blue, 31 dark green and 72 light green) and decreased in 47 (two red, eight orange and 37 yellow). In the North West and Limpopo, reporting rates increased in 85 QDGCs (four blue, 13 dark green and 68 light green) and decreased in 101 QDGCs (19 red, 14 orange and 68 yellow). Much of the Northern Cape part of the range, and 19 QDGCs in the North West and Limpopo had not yet been covered in SABAP2.

National population indices

Agreement between the five national indices calculated for each species using different weightings was strong in all cases (Figures 7–9), despite the fact that some of the weightings for individual precincts varied significantly between sets of weightings (e.g. the Southern Free State weighting for the Blue Korhaan index varied between 0.14 and 0.37; Appendix 4, Table A4.3).

The national index trends for the Blue Korhaan indicated that the species' population within the part of its range covered by the CAR project remained approximately stable or increased slightly over the period covered by the car project (Figure 7; Appendix 4, Table A4.4). According to the summer trend, in 2001, by which time all of the precincts included were being surveyed, the population was at c. 110% of the 2010 level, but the following year it fell to c. 80%, and then increased slowly to c. 130% in 2009, after which it decreased once more. The winter trend was more variable for the years before the majority of the precincts were surveyed, but in 2001 (when all but one of the precincts included were being surveyed) it was c. 85% of 2010 levels, and then increased gradually to 2010 levels with a spike to c. 115% in 2006 and a dip to c. 60% in 2007. The CAR project, and therefore the national index, covered c. 64% of this species' range.

The Karoo Korhaan national index trends were variable from 2002 to 2010 but were increasing overall (Figure 8; Appendix 4, Table A4.5). The summer national index was at c. 80% of the 2010 level in 1999, by which time all but one of the precincts included were being surveyed, and the winter national index was at c. 55% of the 2010 level in that year (all precincts were being surveyed by then). The summer trends showed sharp decreases to c. 40% of the 2010 level in 2004 and to c. 50% in 2008, and peaks of c. 115% in 2006 and 120% in 2009. The winter trends showed a decrease to c. 50% in 2002, and peaks in 2003 and 2008 (c. 120% and c. 145% respectively). However, the proportion of this species' range covered by the CAR project was only c. 16%.

National index trends for the Northern Black Korhaan were variable and the summer and winter trends appeared to be contradictory, but overall they indicated that the portion of the population covered by the CAR project remained approximately stable over the data collection period (Figure 9; Table A4.6). The summer index for 2001 (by which time all the precincts included were being surveyed) was c. 50% of the 2010 level; after a decrease to c. 33% in 2002 it increased sharply to peaks of c. 140% in 2006 and 2008, with another decrease to c. 70% in 2007. The winter index was less variable but decreased and peaked in the same years as the summer index, except for 2006; instead there was a peak of c. 120% in 2004. In 1999 (when all the precincts included were being surveyed) the winter index was c. 115% of the 2010 level, and there were decreases to c. 55% in 2002 and c. 85% in 2007 and a peak of c. 145% in 2008. The CAR project covered c. 12% of this species' range.

Discussion

CAR project

Population trends

Overall from the CAR data it seems that the populations of these three korhaan species were stable or increased over the study period. The only population which decreased to any meaningful extent was that of Blue Korhaans in the Eastern Karoo precinct. Northern Black Korhaan populations in general appeared to be increasing in the CAR precincts, although the summer and winter trends for the Eastern Karoo and North-eastern Free State precincts were contradictory. This phenomenon may have been caused by seasonal differences in behaviour (see below). Karoo Korhaans increased in abundance in the Overberg and Beaufort West precincts, as did Blue Korhaans in the Mpumalanga, North-western Free State and Southern Free State precincts.

These three species are thought to benefit to some extent from extensive agriculture. Both Karoo Korhaans and Northern Black Korhaans include plants typical of disturbed or overgrazed areas in their diets and forage in areas with reduced vegetation cover due to cultivation or heavy grazing (Kok and Earlé 1990, Boobyer and Hockey 1994, Allan 1997a, 1997c). Blue Korhaans often forage in cultivated land, especially in winter, and are attracted to burnt land (Maclean et al. 1983, Collar 1996, Allan 1997b, 2005a). This may explain the overall increase in all three species populations. Intensive agriculture, including irrigation, large areas of monoculture and a high degree of mechanisation, however, is likely to render habitat unsuitable for all three species (Collar 1996, Allan 1997b, 2005a, 2005c).

The apparent decrease in Blue Korhaan numbers in the Eastern Karoo precinct may partly be an artefact of the Underhill index imputing process. Some routes on which many korhaans had been seen in the first few years of surveys in this precinct were not surveyed in the last two or three years, and vice versa for some routes on which low numbers were generally seen. The imputing routine thus generated relatively large totals for some routes not surveyed initially, and small totals for those not surveyed latterly. There is unfortunately no way of gauging the accuracy of these estimates. They may give a realistic reflection of the situation as it was, or may merely have reflected an unfortunate and unusual coincidence. This underlines the importance of the recommendation made by Underhill and Prŷs-Jones (1994) that the fieldwork objective should be to avoid the need to impute missing values if at all possible.

Seasonal discrepancies in numbers of birds observed were all likely to have been a result of seasonal differences in behaviour (Allan 1997a, 1997b, 1997c). None of these korhaans is migratory, although the Northern Black Korhaan has been known to move locally in response to changing conditions (Allan 1997a). It is therefore extremely unlikely that such consistent and widespread seasonal differences in numbers observed reflected actual changes in abundance. Both Blue and Karoo Korhaans, which form long-term breeding partnerships and whose calls are generally territorial, tend to be more secretive in summer when breeding, and more conspicuous in winter (Allan 1997b, 1997c). Shorter vegetation height in winter may also be partially responsible for this change in conspicuousness, especially for the Blue Korhaan which occurs in grassland. Blue Korhaan group size has also been observed to increase in winter (Maclean et al. 1983), which may increase their conspicuousness (Moreira 2006).

In contrast to the Blue and Karoo Korhaans, Northern Black Korhaans are polygynous and females rear their chicks alone, while males display territorially and to attract females year-round (Allan 2005c). Most breeding occurs in summer, and birds display at a significantly higher frequency then. Because these birds are many times more detectable by sound than by sight (SDH pers. obs, Young et al. 2003), it follows that count totals would be lower for winter, when birds were calling less frequently. Count totals for summer are likely to be more reliable than winter totals, because the proportion of the population that is detectable in summer is probably reasonably constant, whereas in winter the males' lower call frequency, which may vary with weather conditions, would cause detection probabilities to be more variable.

Differences in population densities between precincts are consistent for all three species with what one would expect based on an examination of their range maps (Figures 1a–d), and are likely to reflect habitat suitability for each species respectively. Each species' densities were highest in the precincts closest to the core of their ranges, and decreased with distance from the centre of the range, and these differences matched closely differences in atlas reporting rates over their respective ranges (Figures 1b–d).

Habitat use

Blue Korhaans made more extensive use of transformed habitats than would be expected based on existing knowledge (Allan 2005a), although Maclean et al. (1983) did state that the species "frequently [forages] in cultivated lands in winter". It appears that although overall the majority of birds occurred in natural habitats, the species has been able to adapt to make at least some use of a range of transformed habitats. Also, over the time span covered by the CAR project, the populations in precincts in which the species made the most use of transformed habitats increased or remained stable. This implies that the birds may be able to sustain themselves adequately while using these habitats, at least in the short term.

Karoo Korhaans were different from other species analysed in this thesis (Chapters 3, 4 and 5) in that they showed greater preference for transformed habitats in all precincts in summer than in winter. Only Blue Korhaans in the Eastern Karoo precinct showed a similar preference. This may be a consequence of a somewhat earlier breeding season, if the species times its breeding to avoid having young chicks at the hottest, and in some areas driest, time of year. If, as appears to be the case for other species analysed in this thesis, they prefer to use natural habitats when breeding, the breeding cycle may be far enough progressed by late January for this to no longer be a factor in habitat selection (available data on the timing of breeding are not conclusive, however; Allan 2005). Within the range of the Karoo Korhaan natural habitats may in general be harsher in the hot, dry summer than in the cooler, and in some areas wetter, winter; for example transformed habitats may offer a more reliable food supply than natural habitats in summer. Thus transformed habitats may offer greater advantages in summer than in winter. That said, actual numbers of birds in transformed habitats were low in all cases except the Overberg precinct, and observed differences may not be biologically meaningful.

The Karoo Korhaan's habitat use agreed well with existing knowledge (Allan 2005b). The species' extensive use of transformed habitats in the Overberg precinct fits well with the theory that it did not originally occur in this region, but expanded its range into the area in the nineteenth century, after cultivation had become established there (Uys 1981). The transformed habitats in which the species was seen in that precinct were almost all characterised by low or non-existent vegetation cover. This sparse cover is typical of the natural habitat of this species, in contrast to the dense shrub cover of natural Fynbos vegetation.

The extent of Northern Black Korhaans' use of transformed habitats was extremely small, except in the Gauteng precinct in winter. Although the preferred natural habitat of the species is vegetation dominated by grasses 0.5–1.0 m tall, it is also reported to make use of heavily grazed land and areas with sparse and patchy grass cover (Young et al. 2003, Allan 2005c). The transformed habitats in which birds were seen in the present study featured short vegetation or bare ground. The extremely limited degree to which these birds use transformed habitats suggests that this species will come under threat should large parts of its range be cultivated. Indeed the SABAP comparison map (Figure 6c) showed significant declines in reporting rates for this species in at least one region where a large percentage of the land had been transformed by 2009: the Limpopo province (Figure 5 in Chapter 1, SANBI 2009). Nonetheless, in the Free State, a highly transformed province, almost all birds were observed in natural habitats, and the population increased or remained stable. Thus the type of transformation may be important. In Limpopo much of the transformed land was degraded by grazing and mining, rather than cultivated, while almost all transformed land in the Free State was cultivated.

SABAP

SABAP comparison maps

For the Blue Korhaan the SABAP comparison map largely supports the conclusions of the CAR data population trend analysis despite some apparent possible contradictions. For example, the North-eastern Free State precinct, where CAR totals increased, includes more of the area in the SABAP comparison map that shows increased or stable reporting rates than the area in which significant declines in reporting rate were observed (Figures 2a and 6a). The Blue Korhaan's trend for the Eastern Karoo precinct was the only strong negative population trend to emerge from the CAR data in this study, but it was not supported by the SABAP comparison map (Figure 6a). This adds weight to the possibility that the CAR population trend for this precinct was an artefact of the Underhill index imputing process caused by unfortunate combinations of the particular routes which were and were not surveyed in different years.

The SABAP comparison map for the Karoo Korhaan overall agrees with the CAR population trends, except in the Beaufort West precinct. The latter was a very small precinct, however, and only two routes were used for this analysis. These routes did not overlap exactly with the QDGCs in which the significant decreases in reporting rates were observed, and also passed through adjacent QDGCs in which increased reporting rates were observed (Figure 1 in Chapter 1; Figure 6b). Reporting rates in the Overberg region increased overall, similarly to the CAR trends for that precinct, increased somewhat in the Eastern Cape Karoo precinct, as did the winter CAR population trend, and remained stable or decreased slightly overall elsewhere. However, a large part of the species' range had not yet been well covered by SABAP2; the strength of this analysis will increase significantly when SABAP2 coverage of the Northern Cape has improved.

For the Northern Black Korhaan the SABAP comparison map agrees well with the CAR population trends, and indicates that overall the population in the Free State increased, but that it decreased in the relatively small portion of the Eastern Cape karoo occupied by the species. The map implies, however, that the North West and Limpopo populations decreased overall between the SABAP1 and SABAP2 data collection periods, and that coverage of the Northern Cape was not yet sufficient to draw any conclusions about the state of the population in that province. A brief examination of the reporting rates in the Northern Cape QDGCs that have been covered, though, reveals many QDGCs with zero reporting rates for SABAP2. This further highlights the importance of increasing SABAP2 coverage of the region urgently, to improve our knowledge of the status of this and other species occurring there.

National population index

The slight differences between national population indices calculated using the five different types of weighting for all three of these species indicated that, for these species, the national population indices were robust in relation to choice of weights. This can only happen when the indices for the individual series being combined are similar.

The national index trends for all three species showed different characteristics for the years before all the precincts included were being surveyed (indices showed more year-to-year variability for Blue Korhaans and less for Karoo and Northern Black Korhaans). Thus the indices for those early years should be considered only as a rough guide to the population status in those years.

The relatively low degree of variability in the Blue Korhaan's national indices from the first year in which all precincts were being surveyed, and the fact that c. 64% of the range was included, suggests that the CAR project was covering this species well, and that the national population index is reliable for this species. When the summer and winter trends are considered together, the overall conclusion is that this species' population remained stable or increased slightly between 2001 and 2010. The national trend index could be improved further by extending CAR routes into the c. 36% of the range which was not covered by the project. A comparison of the distribution map for the species (Figures 1a and 1b) and the coverage map for the CAR project (Figure 1 in Chapter 1) shows that the area most in need of improved coverage is the northern and central Eastern Cape.

The two species whose ranges were poorly covered by the CAR project, and therefore also by the national trend index (Karoo and Northern Black Korhaans), displayed large inter-annual variability in their national indices. This suggests (a) that the CAR project did not provide sufficient data on these species to calculate a reliable trend for the whole population, and (b) that both species, but especially the Northern Black Korhaan, may move locally to the extent that in some years a significant proportion of the population "normally" covered by the CAR project had moved out of the range of the CAR project. It is unlikely that this inter-annual variability was caused by actual changes in the populations, because these are relatively large-bodied and therefore probably long-lived birds and rates of population change other than dramatic declines caused by major disasters are therefore likely to be low. However, the trends in the national indices indicate that the portions of the populations they cover increased overall over the data collection period.

General

In all three species, population increases that occurred were probably a result of increased breeding territories and more reliable year-round food availability, leading to increased breeding success, in areas where favourable habitat transformation had occurred. All three species used transformed habitats more in one season than the other. It is possible that some times of the year, when conditions are most harsh, may in purely natural habitat function to limit population size by imposing a lower carrying capacity than the environment can support at other times of the year. However, favourable transformed habitats probably provide more reliable food availability than natural land does at these times of the year, which may allow the population to grow to the numbers supportable by the natural environment at the more favourable times of the year. In areas where populations declined, however, the process is likely to have occurred largely as a result of habitat destruction. This would have removed breeding territories and reduced food supplies, resulting in fewer breeding attempts and lower breeding success. Disturbance by humans and domestic animals, and increased chick and egg predation by predators which increased in abundance, such as crows (Chapter 3), probably also contributed to the decline in breeding success.

In a review of the threats faced by bustards in South Africa, Allan and Anderson (2010) assessed the Blue Korhaan as facing a moderate level of threat from habitat destruction resulting from crop farming, mining and human settlement, and recommend that further research be conducted on the impact of these threats on the species. The species is also listed as Near-Threatened both nationally (Barnes 2000) and globally (BirdLife International 2012), because of the threat of habitat destruction and the suspicion that the population has decreased in parts of its range (Allan 2005a). The results presented here, however, suggest that the species is at present under no immediate threat and able to utilise transformed habitats to a degree sufficient to ensure its continued survival at present levels. However, should habitat transformation increase or change in form within this species' range it may affect the species adversely, and we therefore recommend that it remain classified as Near-Threatened.

Allan and Anderson (2010) considered that Karoo Korhaans face possible threats from poisoning during locust control operations, and from climate change. However, at the end of the study period, in 2010, their population appeared to be stable overall, or possibly slightly increasing (in the part of the range covered by the CAR project at least), so it would appear that these threats had not by that stage materialised. The species is less likely to be severely affected by poisoning incidents than species such as Blue Cranes or Ludwig's Bustards *Neotis ludwigii* which form large flocks; only one or two family groups would be likely to be affected by any one incident. This threat could nevertheless become significant if the scope of such locust control operations were to increase. Climate change is likely to be a relatively slow-acting threat, and its effects on a species such as this are unlikely to become detectable for decades. However, the species occupies a large range reaching into Namibia (Allan 2005b), and because its preferred habitat is hot, dry, sparsely vegetated areas, which are likely to increase under climate change, this species is hypothesised to be likely to benefit from climate change rather than to be under threat.

The Northern Black Korhaan was assessed as being under a moderate level of threat from habitat destruction caused by crop farming (Allan and Anderson 2010). This is borne out by the habitat-use data; this species appeared to avoid transformed areas if at all possible, except in Gauteng in winter. The SABAP comparison map also suggested that some types of land transformation in particular may be more of a threat than others, because even in some heavily transformed areas, such as the north-western Free State (Figure 5b in Chapter 1), the birds generally avoided using transformed habitats, and their population appears to have increased over the same time period (Figure 6c).

Conclusions

Although the populations of all three of these species appear to have been stable over the study period, it is important to continue monitoring them, as there are many potential threats to their survival which may appear or may already be acting on them.

In particular, CAR project coverage of the Eastern Cape should be increased if possible, to better cover the range of the endemic Blue Korhaan. It is critical that SABAP2 coverage of the Northern Cape, especially, but also poorly covered parts of other provinces, be increased as soon as possible, to gain a better idea of the status of the Karoo and Northern Black Korhaans' populations as a whole. Both depth (number of atlas surveys per pentad) and breadth of coverage need to be increased urgently. All three of these species appear to be able to make use of transformed land to some extent, but if the predominant type of land use should change, this could constitute a serious threat to these birds. It is therefore vital that the monitoring effort is continued and increased so that any changes in their population status are detected timeously.

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Table 1: Summary of population trend analysis data for the Blue Korhaan (BK), Karoo Korhaan (KK) and Northern Black Korhaan (NBK) from the Coordinated Avifaunal Roadcounts (CAR) project. The column "Number of routes" gives the number of routes that were surveyed at least six times in either summer or winter. Average route lengths were calculated from these routes. "Number of years" gives the longest series used in the analysis. "Start year" gives the earliest year from which data were used for this analysis. The total columns give the total number of birds seen in these precincts on all routes and in both summer and winter, from the first year in which the precinct was surveyed until 2010 inclusive. Figures are only included for analysed precincts, even though small numbers of each species may have been recorded in other precincts.

Precinct	Number of routes	Ave. route length (km)	Start year	Number of years	Total BK	Total KK	Total NBK
Beaufort West	2	59.9	1998	12		782	
Eastern Cape Karoo	20	57.8	1998	13		1 251	1 323
Eastern Karoo	22	58.8	1996	15	696	1 170	3 444
Mpumalanga	11	60.5	2003	8	244		
North-eastern Eastern Cape	20	54.8	2001	10	1 180		
North-eastern Free State	29	60.7	1998	13	1 384		1 525
North-western Free State	21	61.8	1999	12	358		8 849
Overberg	33	54.7	1997	14		1 015	
Southern Free State	78	65.2	1997	14	8 900		34 272
Wakkerstroom	7	62.2	2000	11	331		
Total					13 093	4 218	49 413

Table 2: Adjustments made to Blue, Karoo and Northern Black Korhaan data used for the Underhill index analysis. Seasons are abbreviated as S for summer and W for winter. In the comments column, "species not yet reliably counted" refers to the fact that it often took a year or two before all CAR observers in a precinct became aware that new species had been included in the project if it was not included from the start of that precinct (DJ Young, pers. comm.), which applied to these species in most of the precincts.

Precinct	Season	Adjustment	Comments
		Blue Korhaan	
Eastern Karoo	S & W	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
	S	1998 excluded	Too few routes were surveyed this year for the imputed totals to be realistic; species not yet reliably counted
Mpumalanga	W	1998 to 2002 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
North-eastern Eastern Cape	S	1999 and 2000 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
	W	1998 excluded	Too few routes were surveyed this year for the imputed totals to be realistic; species not yet reliably counted
North-eastern Free State	S	1998 to 2000 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
	W	1997 and 1998 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
Southern Free State	W	1997 and 1998 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
		Karoo Korhaan	
Eastern Karoo	S	2009 and 2010 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
	W	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
	W	1995 and 1996 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
		Northern Black Korhaan	
Eastern Cape Karoo	S	1999 excluded	Too few routes were surveyed this year for the imputed totals to be realistic; species not yet reliably counted
	W	1998 excluded	Too few routes were surveyed this year for the imputed totals to be realistic; species not yet reliably counted
Eastern Karoo	S	1998 to 2000 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
	W	Included only routes surveyed at least seven times	The percentage imputed was too high if routes that had been surveyed only six times were included
	W	1997 and 1998 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic; species not yet reliably counted
North-eastern Free State	S	1998 to 2000 excluded	Too few routes were surveyed in these years for the imputed totals to be realistic
	W	1997 excluded	Too few routes were surveyed this year for the imputed totals to be realistic; species not yet reliably counted

Table 3: Habitat selection analysis for Coordinated Avifaunal Roadcounts data for (a) Blue Korhaans, (b) Karoo Korhaans and (c) northern Black Korhaans for the precincts for which there were sufficient data (see text), summer (S) and winter (W) counts. Jacobs index *D* values indicate selection for natural habitat if positive and for transformed land if negative. Numbers in the Natural and Transformed columns are the numbers of routes on which a preference was shown for natural and transformed habitats respectively. Sign test *p* values refer to tests of whether the number of routes with positive Jacobs index *D* values was significantly different from that expected if zero selection had been shown.

(a)

Precinct	Season	Jacobs index *D*	Natural	Transformed	Sign test *p* value
Eastern Cape Karoo	S	–0.686	3	2	0.655
	W	–0.690	3	2	0.655
Eastern Karoo	S	–0.741	26	5	< 0.001
	W	–0.228	27	2	< 0.001
Mpumalanga	S	0.502	7	2	0.096
	W	0.118	6	3	0.317
North-eastern Eastern Cape	S	–0.023	5	5	1.000
	W	–0.516	5	6	0.763
North-eastern Free State	S	0.427	20	11	0.106
	W	–0.046	22	19	0.639
North-western Free State	S	0.885	16	2	< 0.001
	W	0.921	11	1	0.004
Southern Free State	S	0.162	73	32	< 0.001
	W	–0.101	63	45	0.083
Wakkerstroom	S	0.527	9	0	0.003
	W	–0.712	3	5	0.480

(b)

Precinct	Season	Jacobs index	Natural	Transformed	Sign test *p* value
Eastern Cape Karoo & Beaufort West	S	0.409	15	3	0.005
	W	0.422	15	3	0.005
Eastern Karoo	S	–0.139	60	2	< 0.001
	W	0.057	60	5	< 0.001
Little Karoo	S	–0.475	1	4	0.180
	W	0.330	5	1	0.102
Overberg	S	–0.166	4	10	0.109
	W	0.029	6	8	0.593
Southern Free State	S	–0.216	11	2	0.013
	W	0.808	15	1	< 0.001

(c)

Precinct	Season	Jacobs index	Natural	Transformed	Sign test *p* value
Eastern Cape Karoo	S	0.836	8	0	0.005
	W	–0.045	6	1	0.059
Eastern Karoo	S	0.523	61	4	< 0.001
	W	0.249	58	2	< 0.001
Gauteng	S	0.858	18	2	< 0.001
	W	0.100	12	6	0.157
North-eastern Free State	S	0.845	9	3	0.083
	W	0.717	14	6	0.074
North-western Free State	S	0.898	40	4	< 0.001
	W	0.881	43	2	< 0.001
Southern Free State	S	0.767	107	10	< 0.001
	W	0.691	106	12	< 0.001

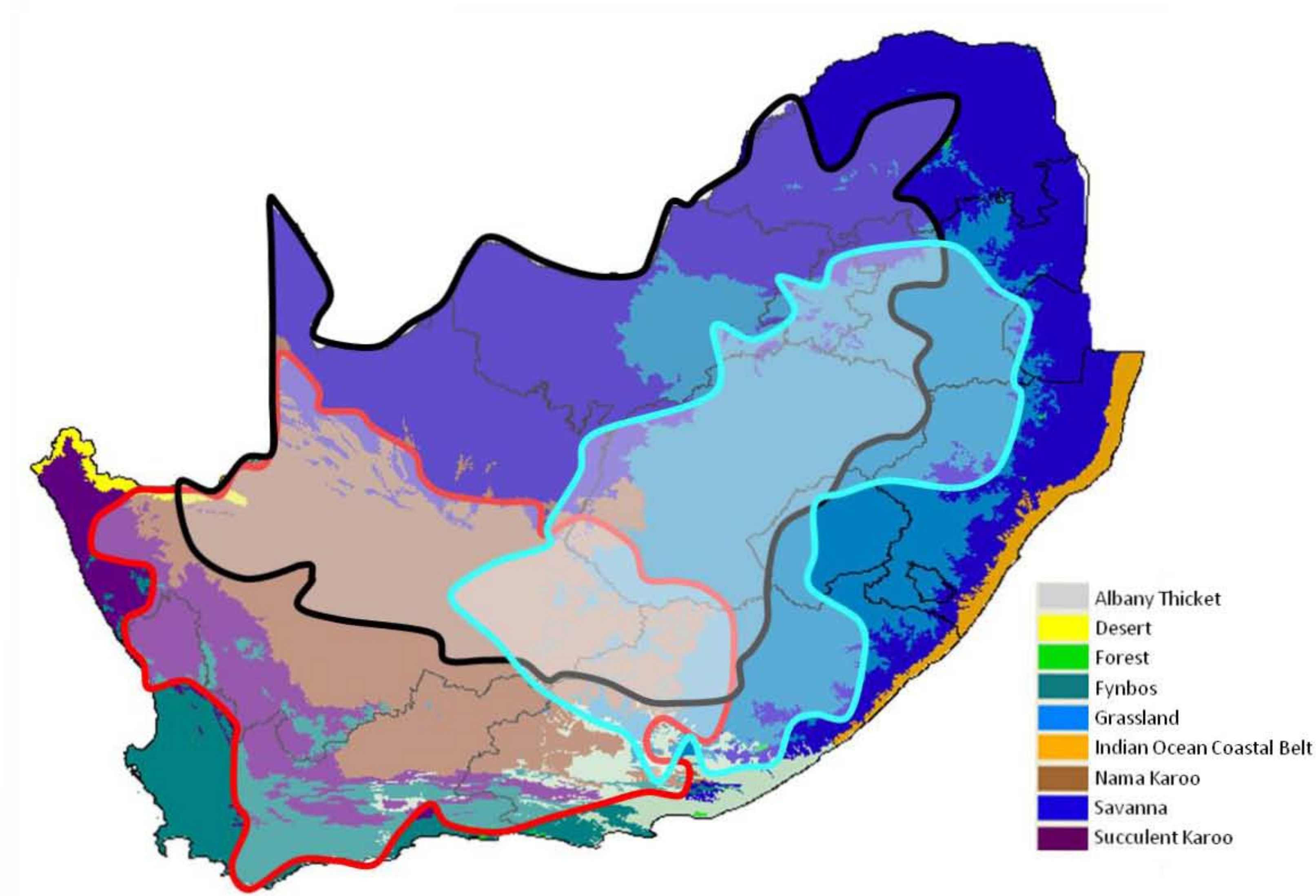

Figure 1a: Biomes (Mucina and Rutherford 2006) and outlines of the ranges of the Blue Korhaan (blue), Karoo Korhaan (red) and Northern Black Korhaan (black), drawn using data from SABAP1 (Allan 1997a, 1997b, 1997c) and SABAP2 (presented below).

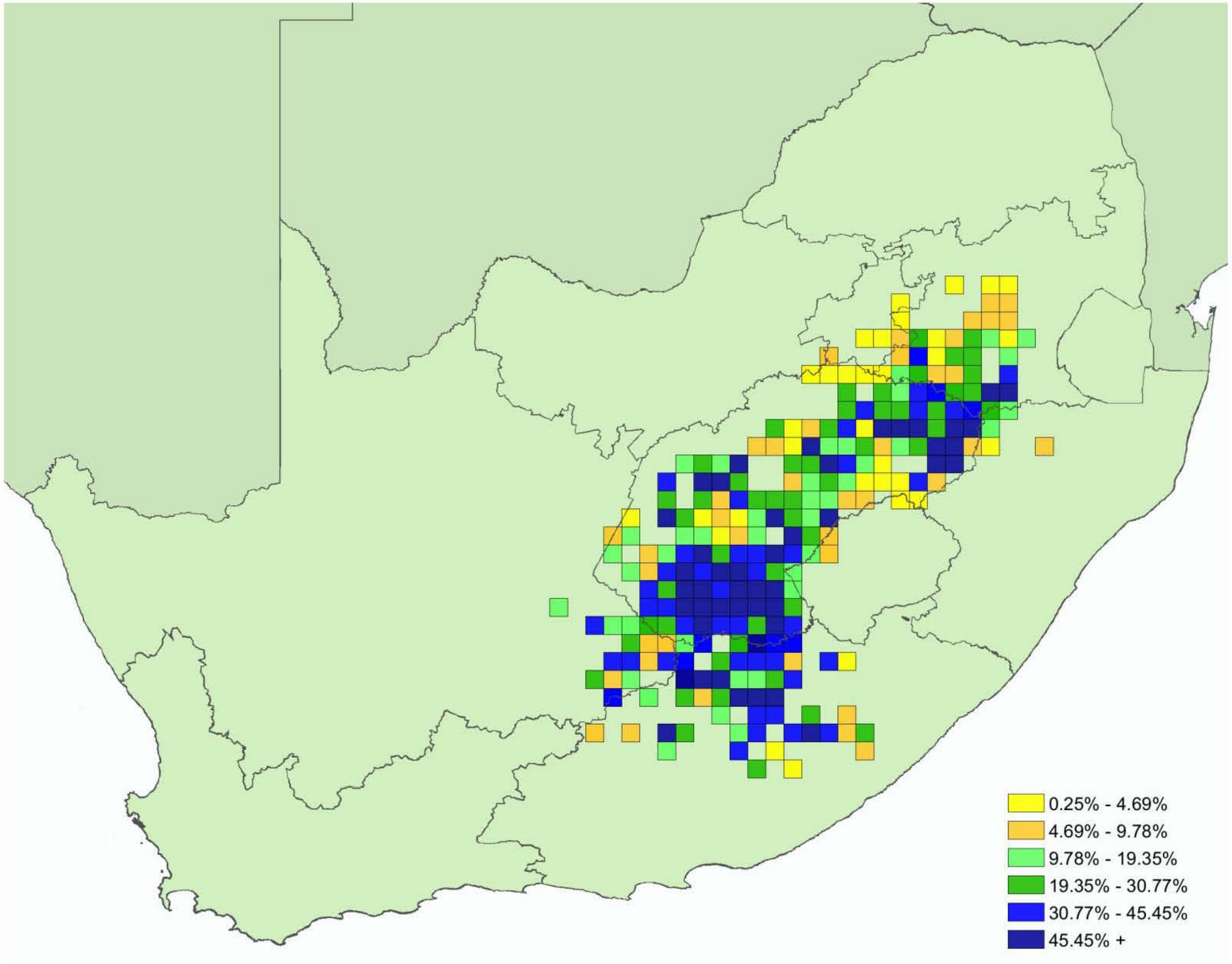

Figure 1b: Range map for the Blue Korhaan showing derived reporting rates calculated from SABAP1 and SABAP2 data, extracted on 10 February 2012. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15'). Derived reporting rates were calculated as described in Chapter 1.

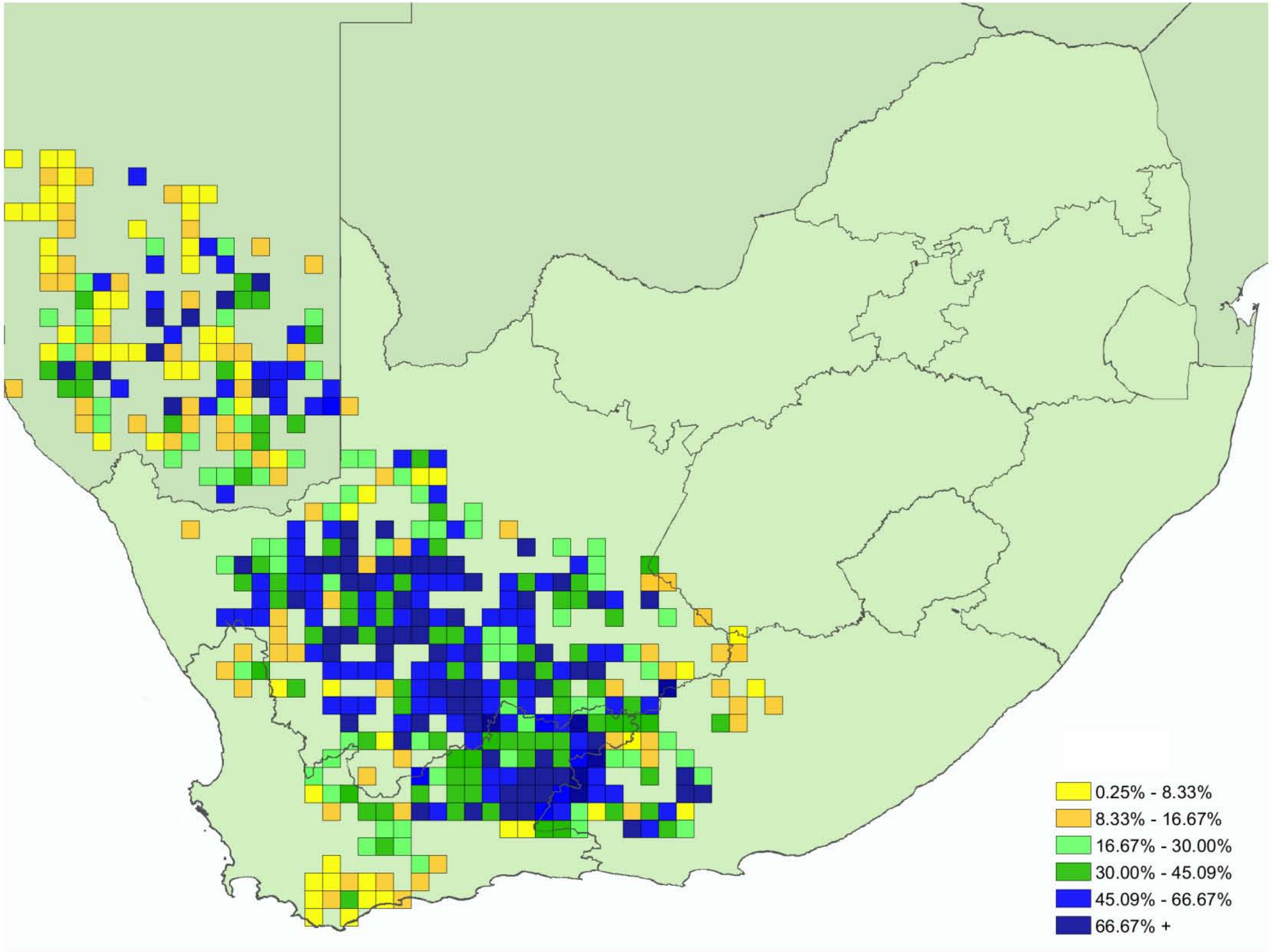

Figure 1c: Range map for the Karoo Korhaan constructed as for Figure 1b.

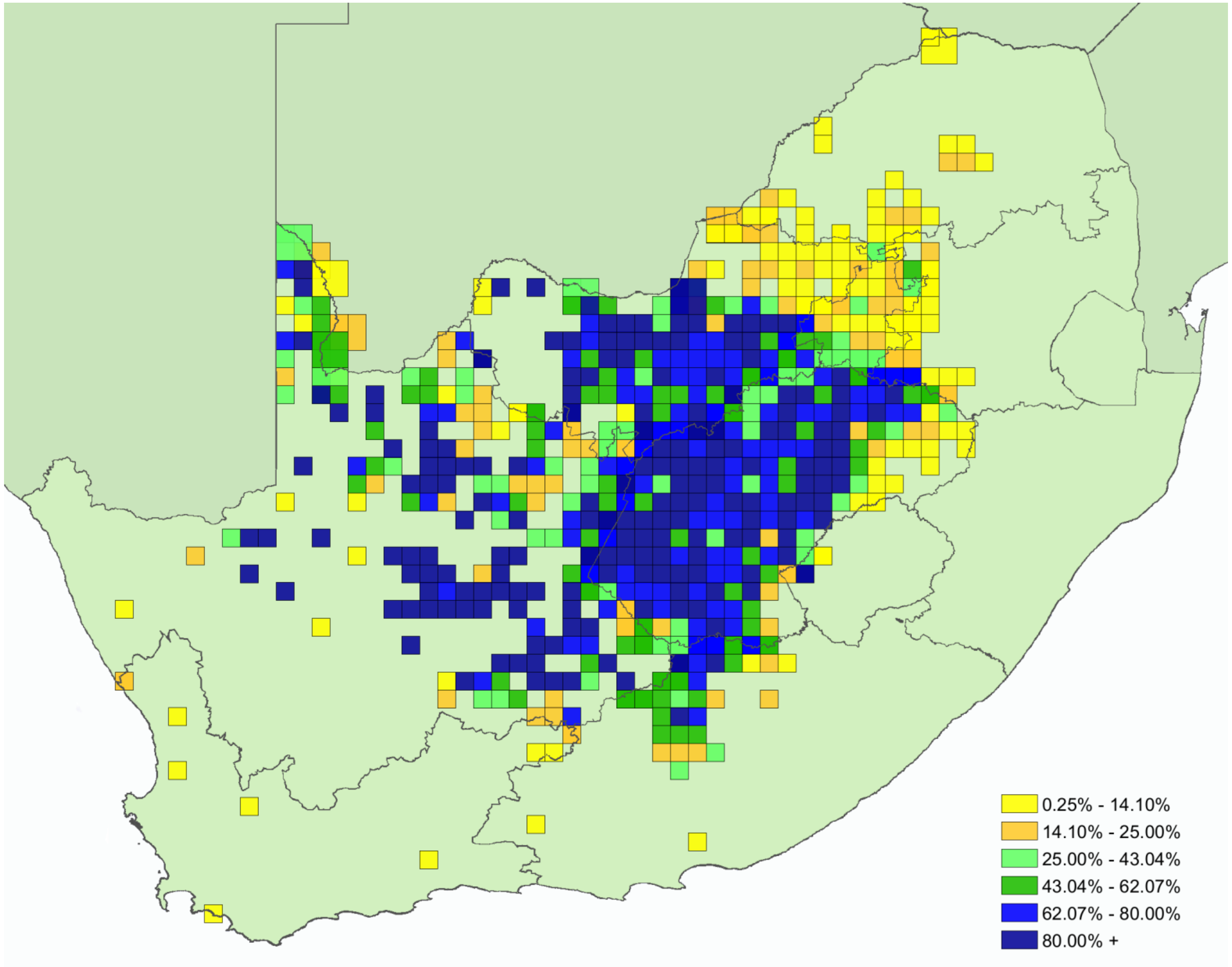

Figure 1d: Range map for the Northern Black Korhaan constructed as for Figure 1b. Coloured QDGCs within the range of the Southern Black Korhaan (Figure 1a) are an artefact of the complication of data vetting for species that were split since 1992 and should be ignored.

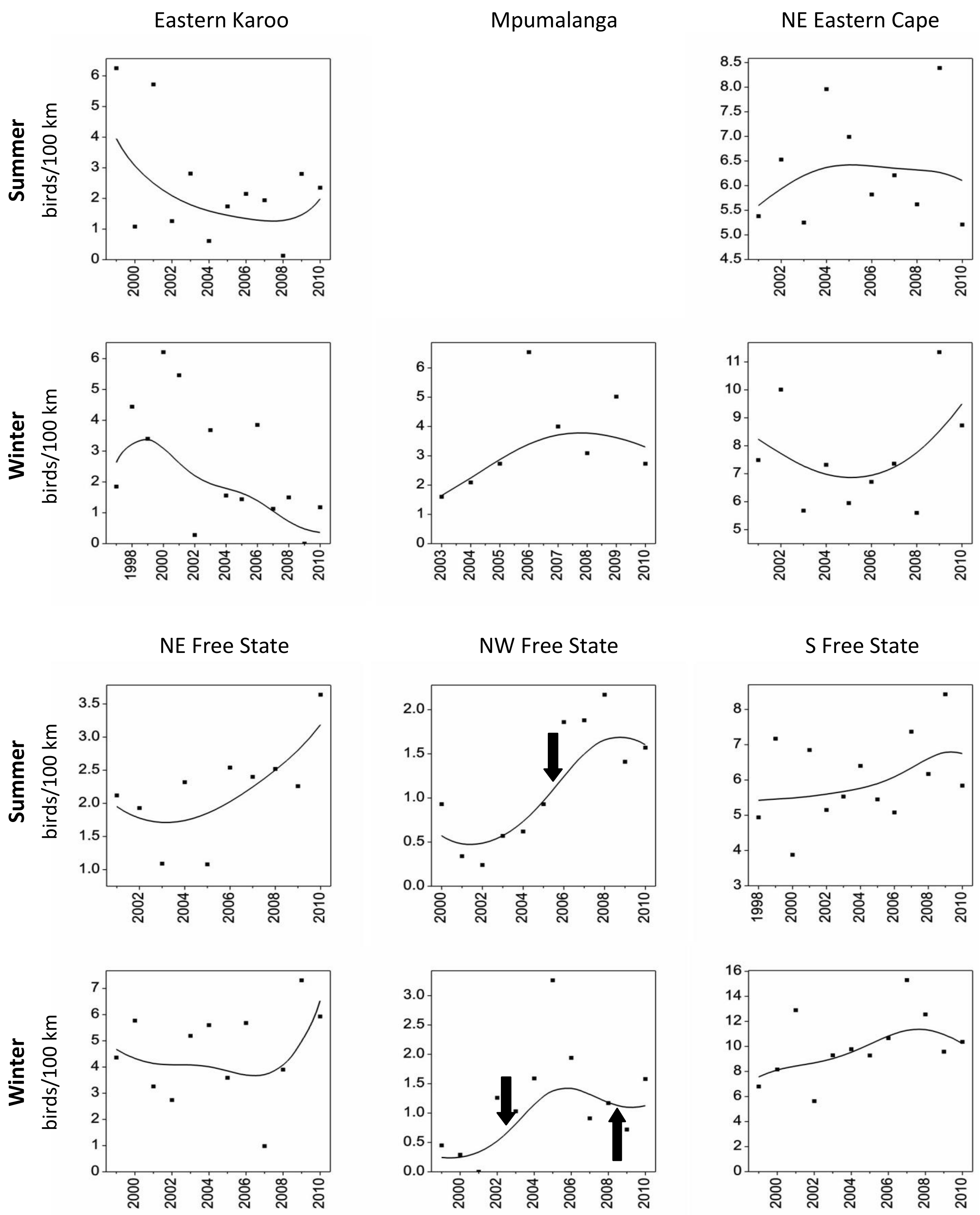

Figure 2a: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Blue Korhaan for the Eastern Karoo (summer: 877 km; winter: 706 km), Mpumalanga (550 km), North-eastern Eastern Cape (summer: 877 km; winter: 929 km), North-eastern Free State (summer: 1 631 km; winter: 1 692 km), North-western Free State (summer: 966 km; winter: 1 270 km) and Southern Free State (summer: 5 052 km; winter: 4 511 km) precincts (Figure 1 in Chapter 1) for summer and winter counts. Arrows indicate relevant points of inflection in the trends; up arrows indicate where the rate of change went from negative to positive, and down the reverse.

Wakkerstroom

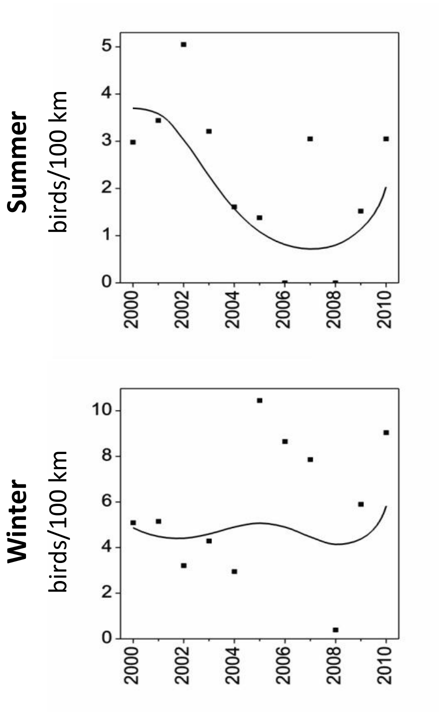

Figure 2b: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Blue Korhaan for the Wakkerstroom (summer: 436 km; winter: 373 km) precinct (Figure 1 in Chapter 1) for summer and winter counts.

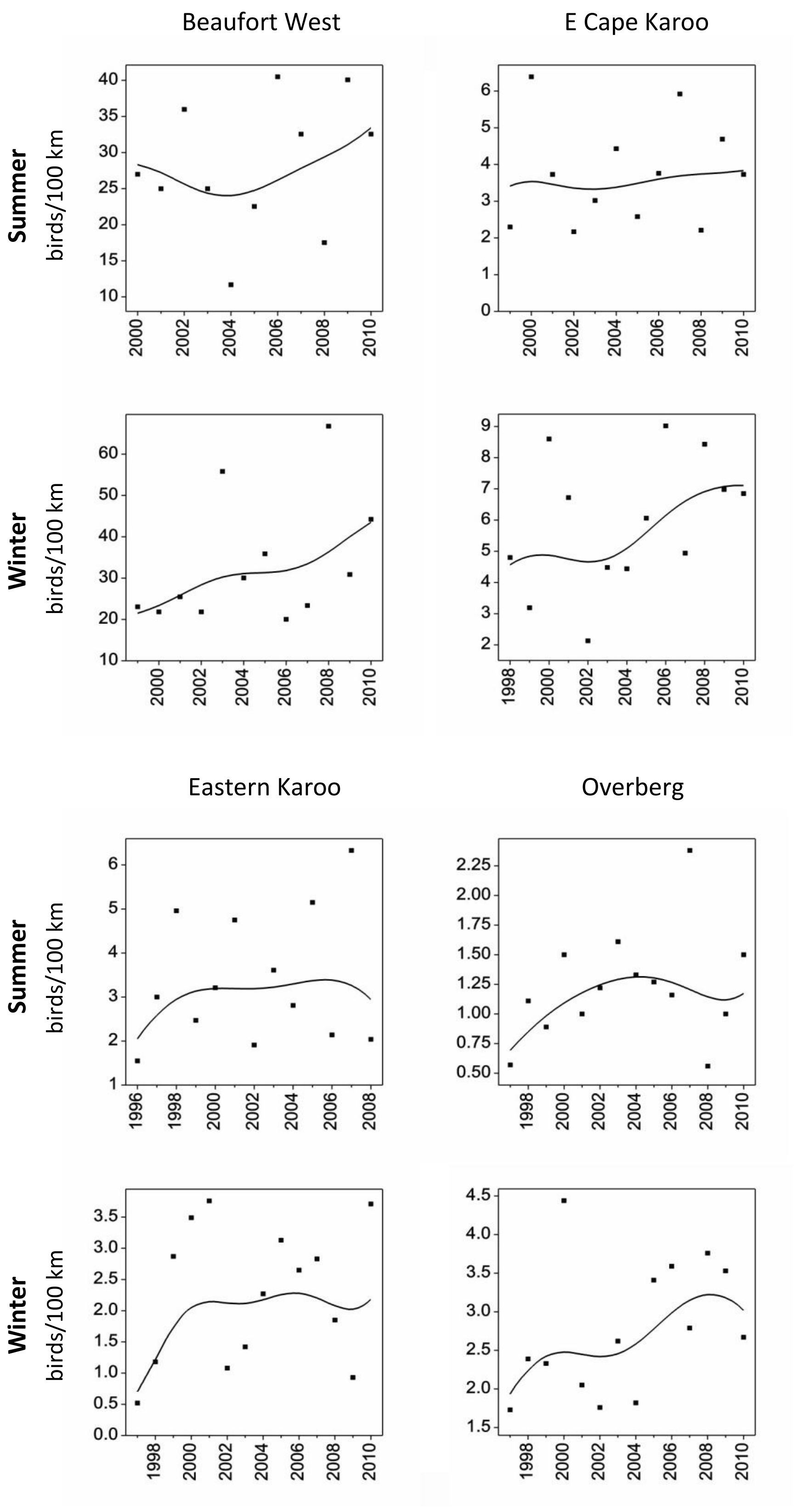

Figure 2c: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Karoo Korhaan for the Beaufort West (120 km), Eastern Cape Karoo (summer: 1 063 km; winter: 1 155 km), Eastern Karoo (summer: 1 115 km; winter: 706 km) and Overberg (summer: 1 806 km; winter: 1 757 km) precincts (Figure 1 in Chapter 1) for summer and winter counts.

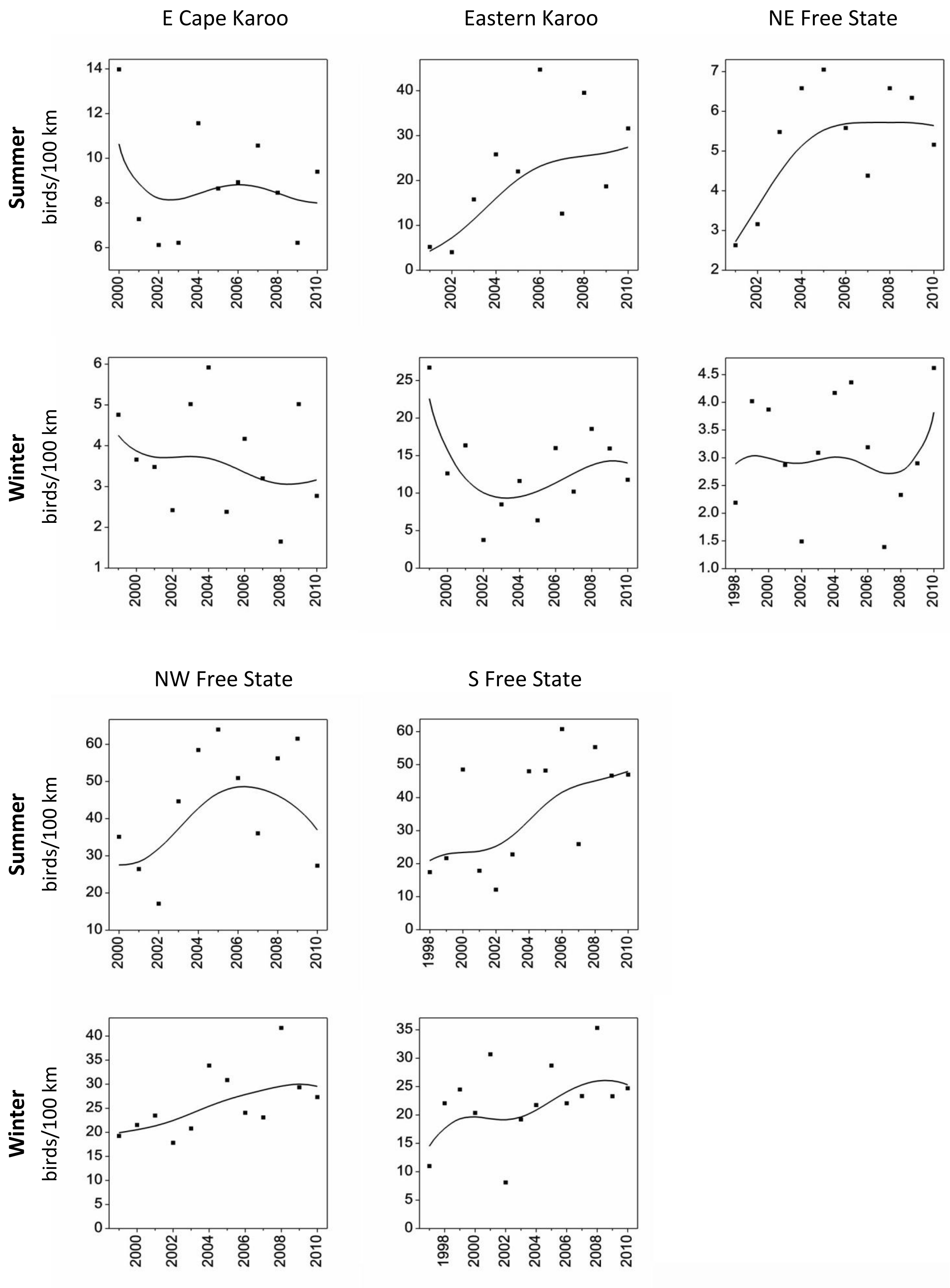

Figure 2d: Weighted linear regressions fitted to annual CAR count data (birds/100 km) for the Northern Black Korhaan for the Eastern Cape Karoo (summer: 1 063 km; winter: 1 155 km), Eastern Karoo (summer: 911 km; winter: 706 km), North-eastern Free State (1 790 km), North-western Free State (summer: 966 km; winter: 1 270 km) and Southern Free State (summer: 5 052 km; winter: 4 511 km) precincts (Figure 1 in Chapter 1) for summer and winter counts.

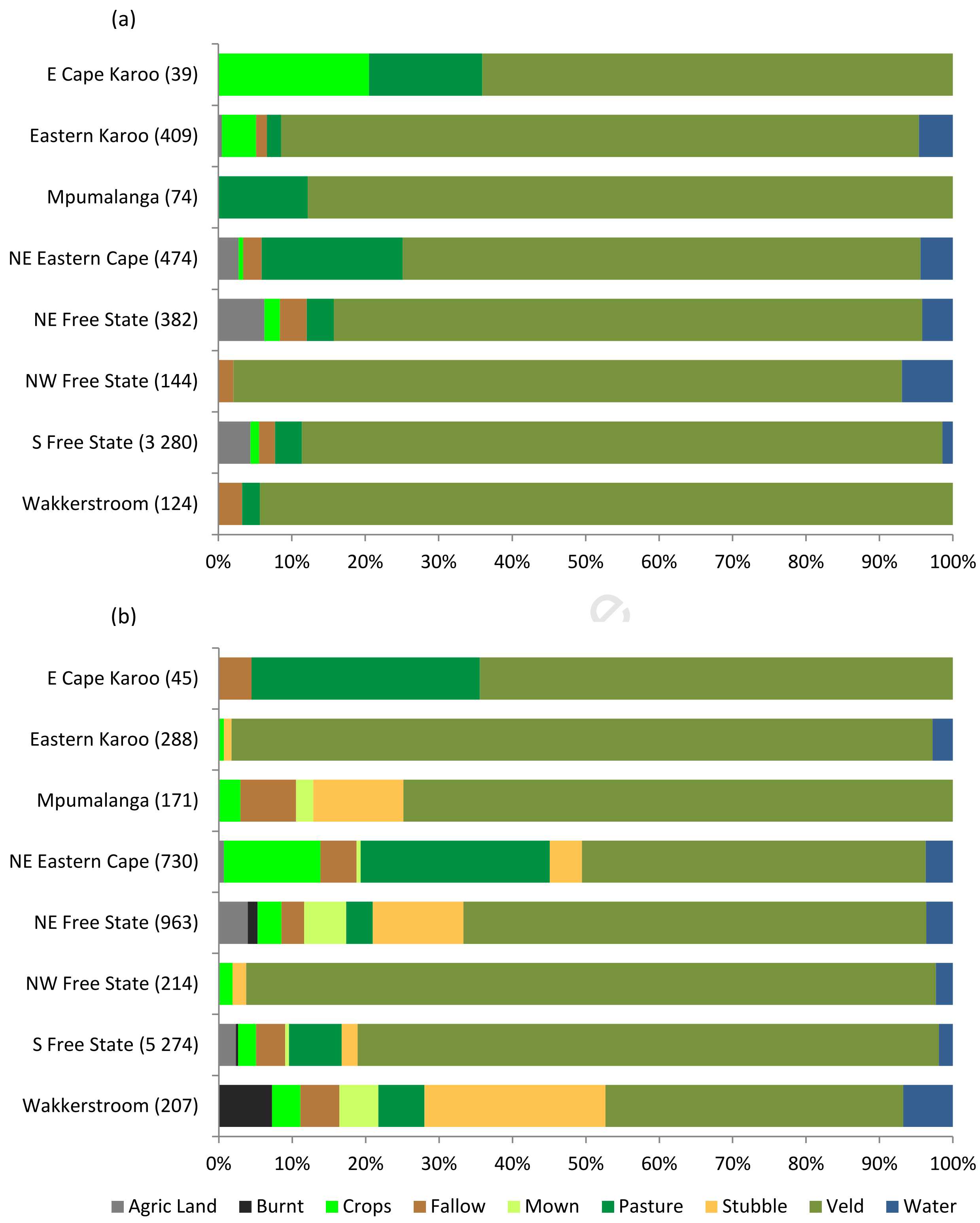

Figure 3: CAR habitat use data for Blue Korhaans for (a) summer and (b) winter counts, for the eight precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in surveys conducted in that season. "Agric Land" for summer includes ploughed, burnt and mown land, crop stubble fields and other miscellaneous types of farmland, but for winter includes only ploughed land and miscellaneous farmland; "crops" includes all cultivated crops, orchards and vineyards, and "stubble" is harvested crop fields.

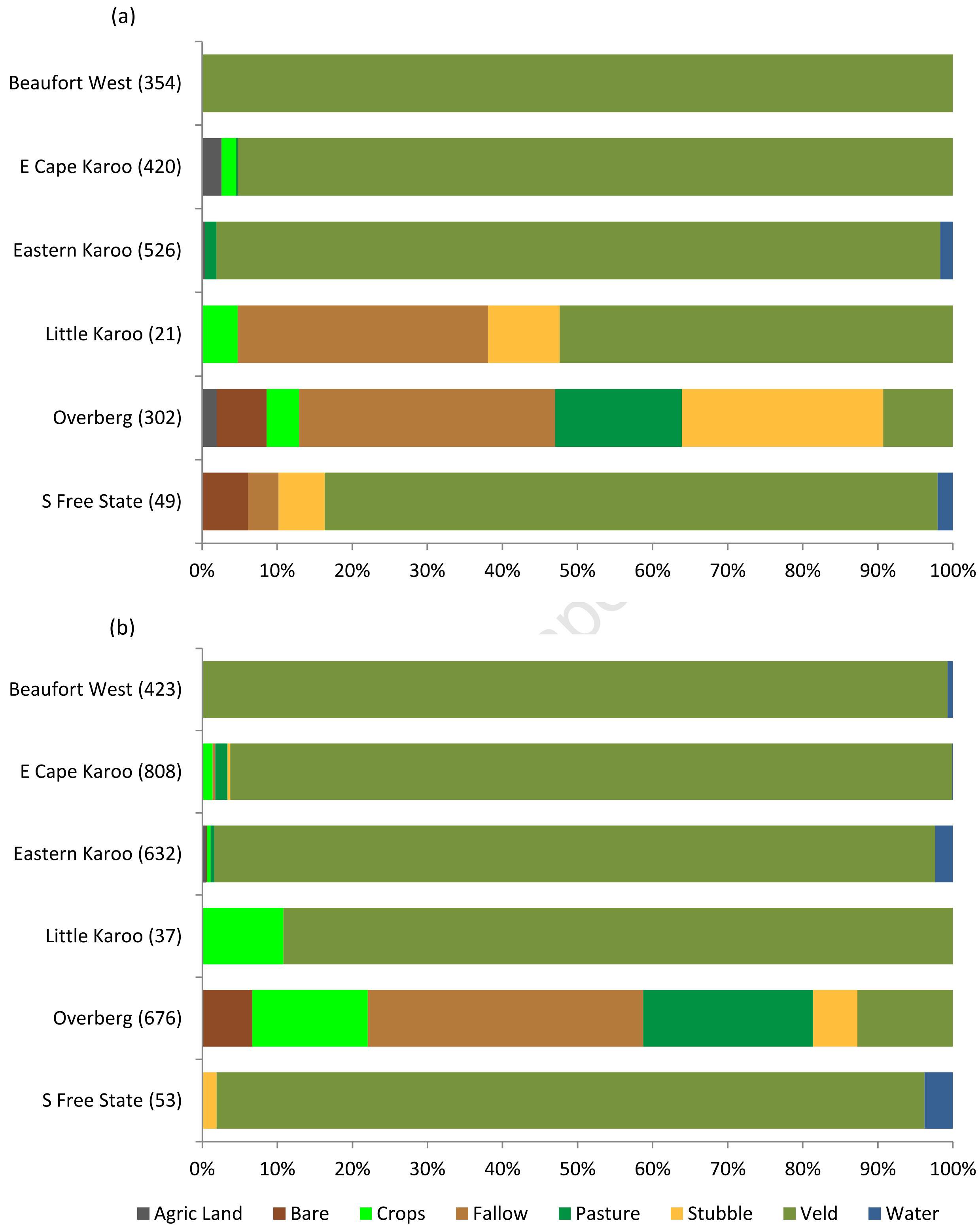

Figure 4: CAR habitat use data for Karoo Korhaans for (a) summer and (b) winter counts, for the six precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in surveys conducted in that season. "Agric Land" includes mown land and other miscellaneous types of farmland; "bare" indicates ploughed land, "crops" includes all cultivated crops, orchards and vineyards, and "stubble" is harvested crop fields.

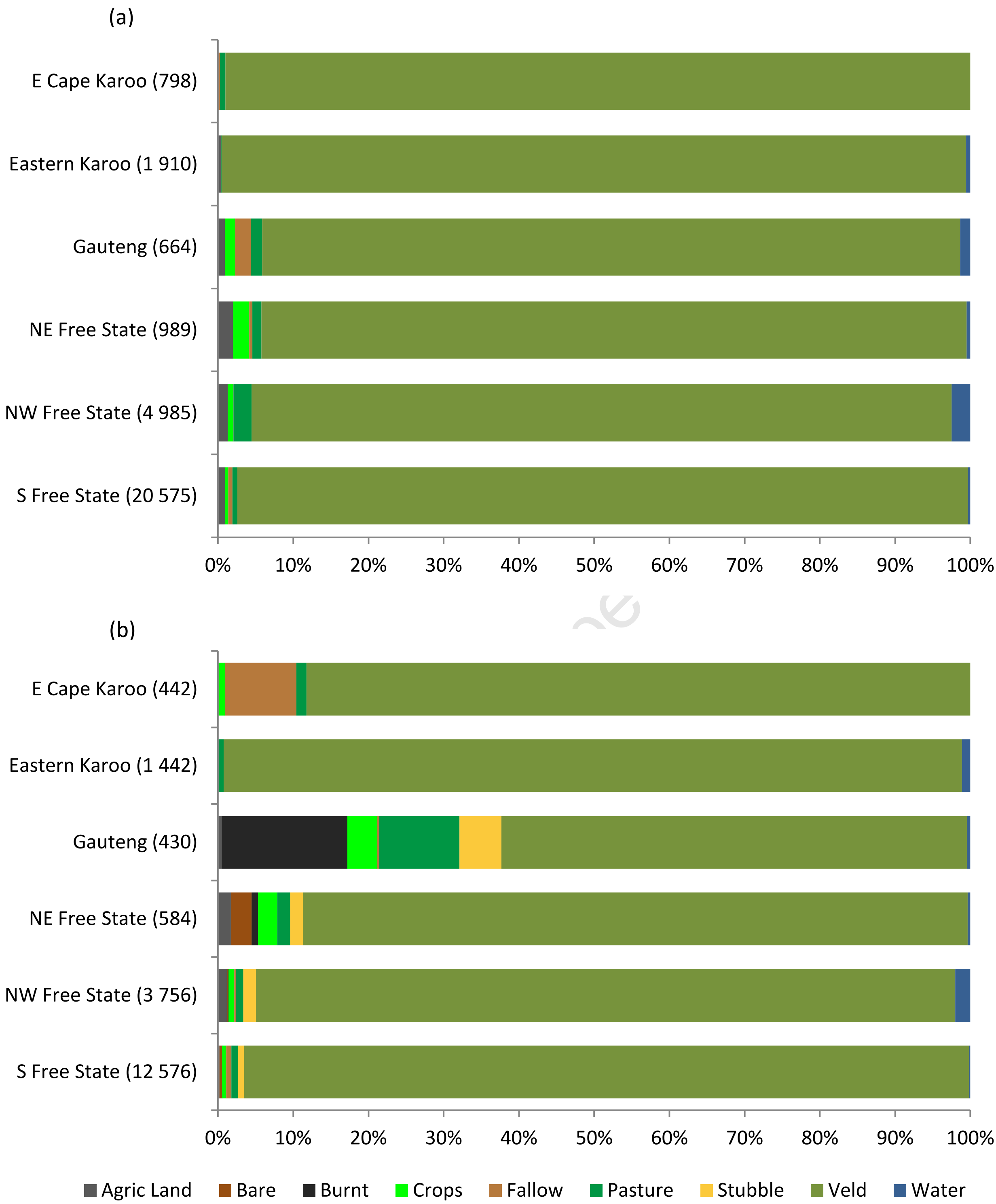

Figure 5: CAR habitat use data for Northern Black Korhaans for (a) summer and (b) winter counts, for the six precincts for which there were sufficient data for habitat selection analyses. Numbers in brackets following the precinct name give the total number of birds recorded in that precinct in surveys conducted in that season. "Agric Land" for summer includes ploughed, burnt and mown land, crop stubble fields and other miscellaneous types of farmland, but for winter includes only mown land and miscellaneous farmland; "bare" indicates ploughed land, "crops" includes all cultivated crops, orchards, vineyards and plantations, and "stubble" is harvested crop fields.

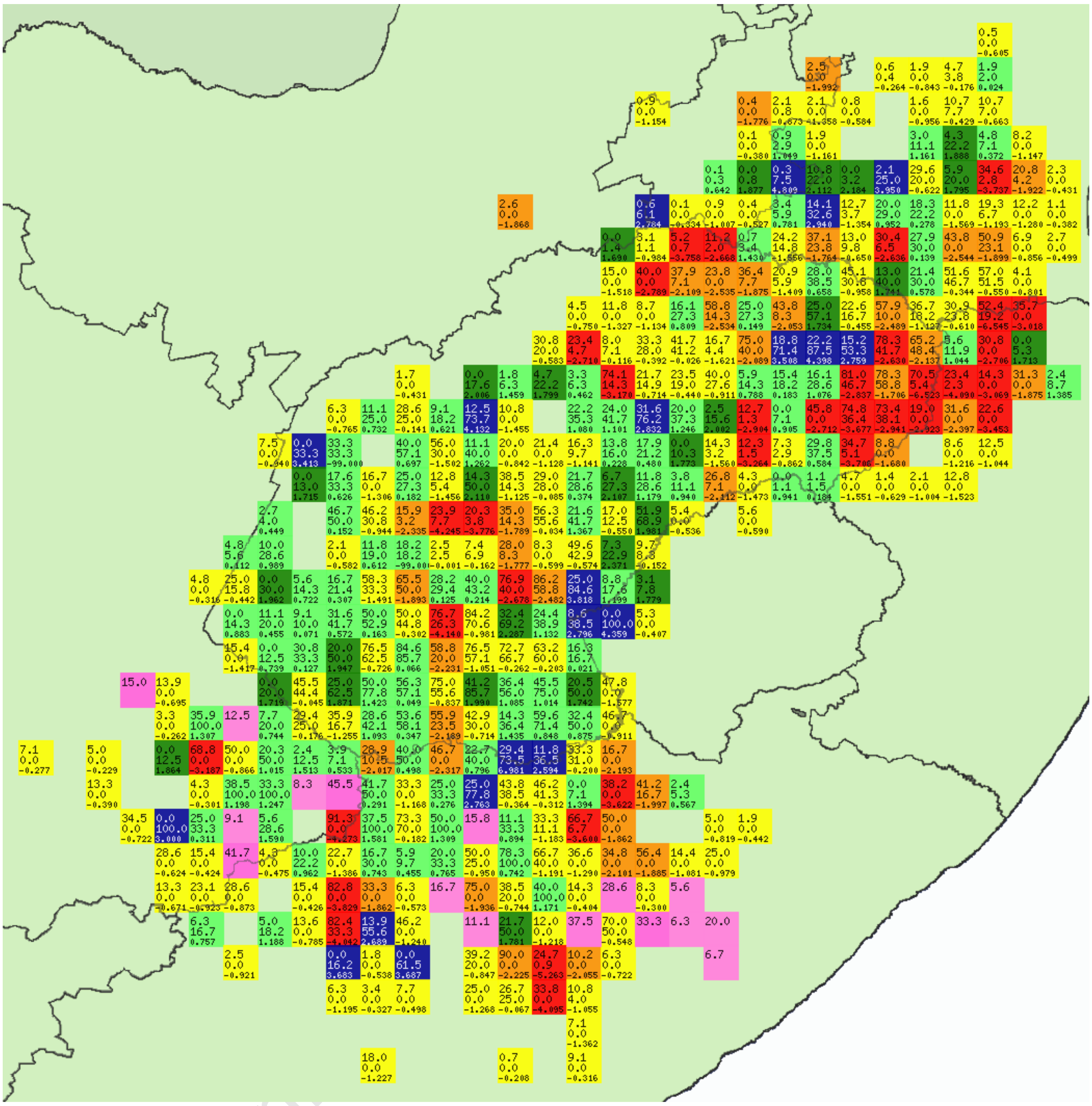

Figure 6a: SABAP comparison map for the Blue Korhaan, extracted on 10 February 2012. This map compares SABAP1 and SABAP2 reporting rates. Coloured squares are quarter-degree grid cells (QDGCs; 15' × 15') in which the species was observed in either project. Reporting rates are compared using the *Z* statistic (see text). The upper number in each square is the SABAP1 reporting rate, the middle number is the SABAP2 reporting rate, and the lower number is *Z*. SABAP2 reporting rates for were lower than SABAP1 in red, orange and yellow grid cells, and higher than SABAP1 for light and dark green and blue grid cells. In red grid cells $Z < -2.58$, in orange $-2.58 < Z < -1.64$, and in yellow $-1.64 < Z < 0$. In light green grid cells $0 \leq Z < 1.64$, in dark green $1.64 < Z < 2.58$, and in blue grid cells $Z > 2.58$. Pink grid cells are those which had not yet been covered in SABAP2. Therefore, red, orange and yellow grid cells indicate areas of potential conservation concern, whereas green and blue grid cells indicate areas of apparent population increase.

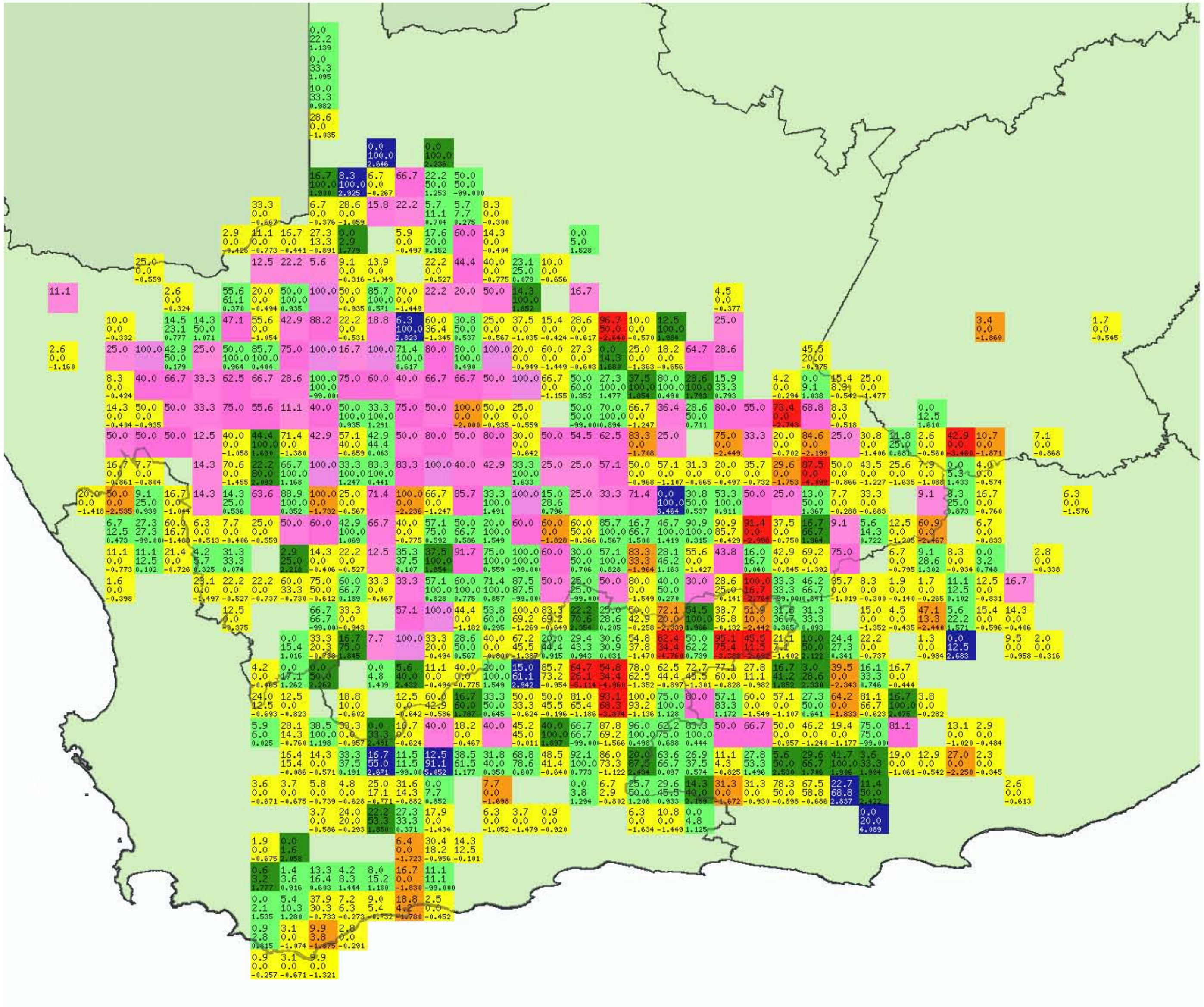

Figure 6b: SABAP comparison map for the Karoo Korhaan, extracted on 10 February 2012. Constructed as for Figure 6a.

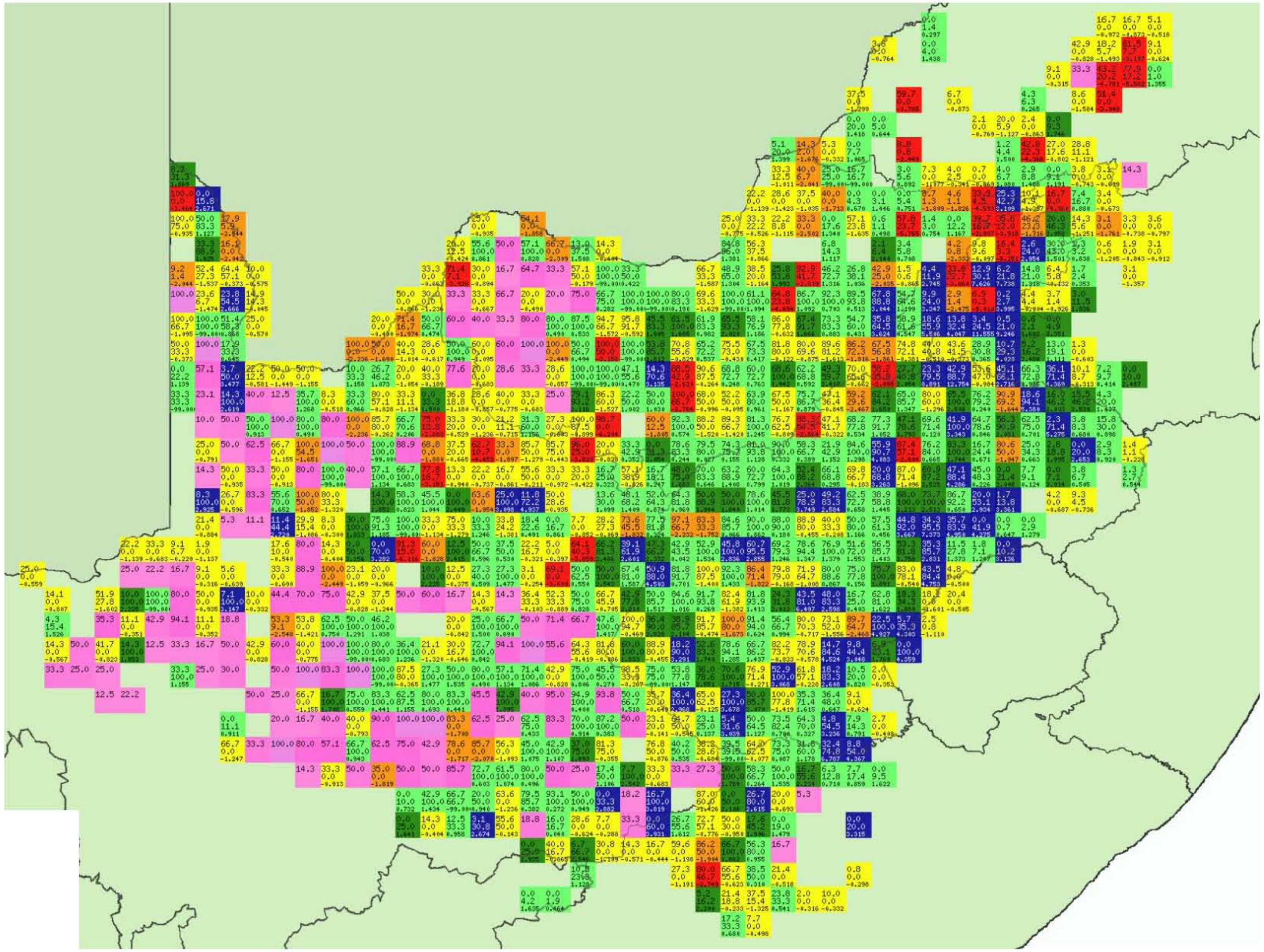

Figure 6c: SABAP comparison map for the Northern Black Korhaan, extracted on 10 February 2012. Constructed as for Figure 6a. Data for the Southern Black Korhaan have been deleted.

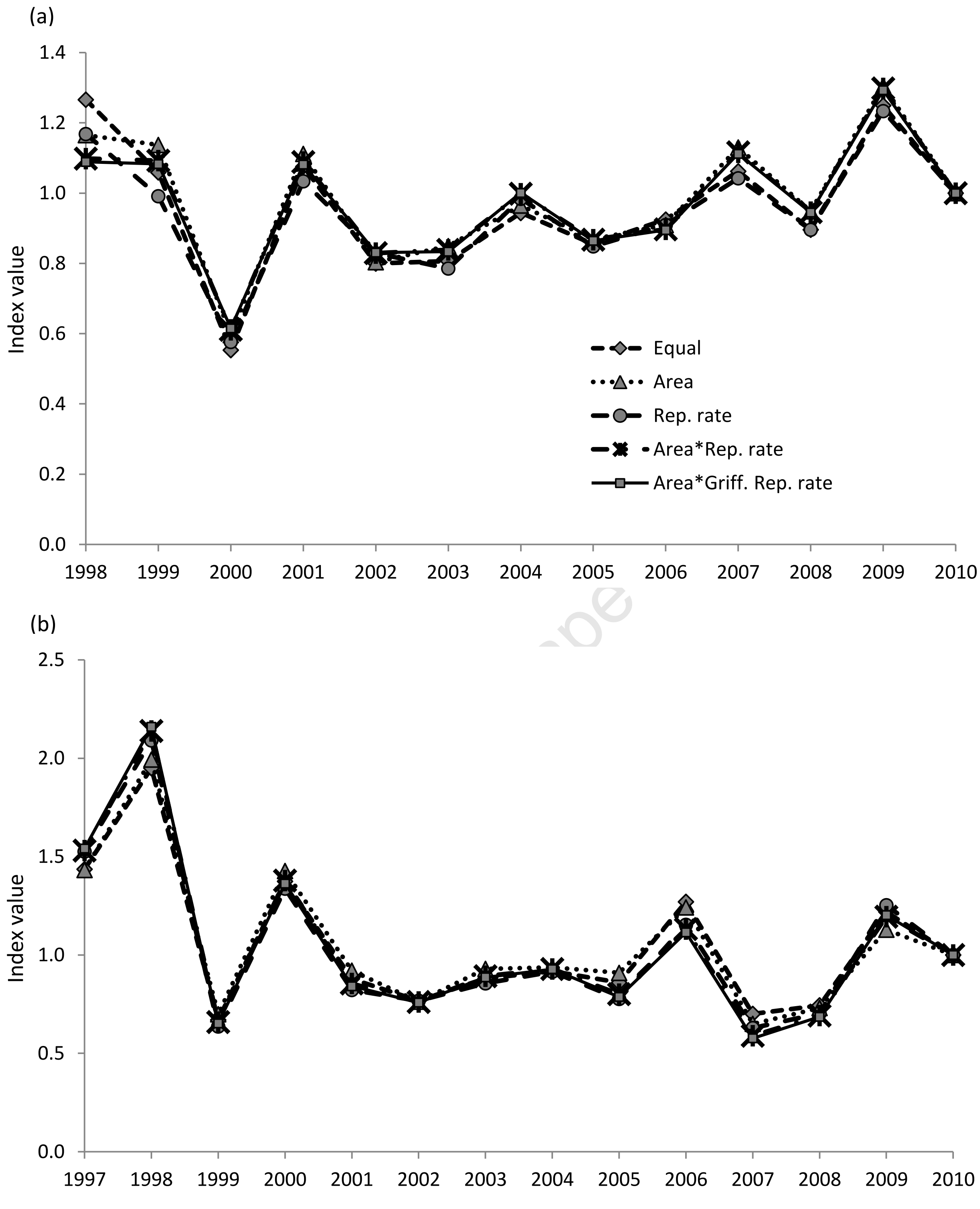

Figure 7: National indices for Blue Korhaans for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weights, each one represented by one set of points and a line. "Equal" had equal weights for each precinct. "Area" had precincts weighted by their relative area, and "Rep. rate" had precincts weighted by SABAP1 reporting rates for Southern Black Korhaans for that precinct. "Area*Rep. rate" weights used area and reporting rate multiplied together, and "Area*Griff. Rep. rate" used area multiplied by the logarithmic conversion of reporting rates suggested by Griffioen (2001).

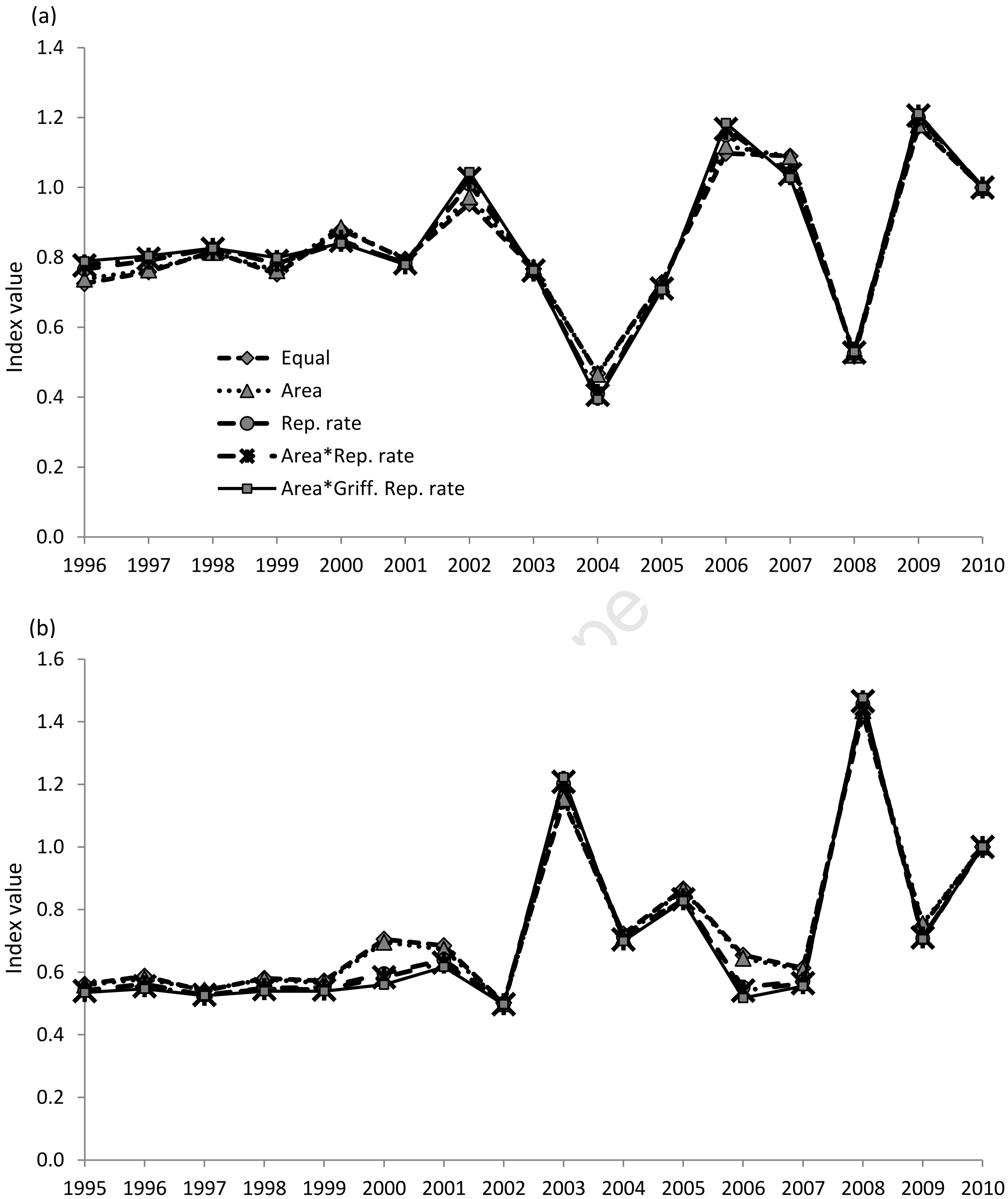

Figure 8: National indices for Karoo Korhaans for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weights, each one represented by one set of points and a line. "Equal" had equal weights for each precinct. "Area" had precincts weighted by their relative area, and "Rep. rate" had precincts weighted by SABAP1 reporting rates for Southern Black Korhaans for that precinct. "Area*Rep. rate" weights used area and reporting rate multiplied together, and "Area*Griff. Rep. rate" used area multiplied by the logarithmic conversion of reporting rates suggested by Griffioen (2001).

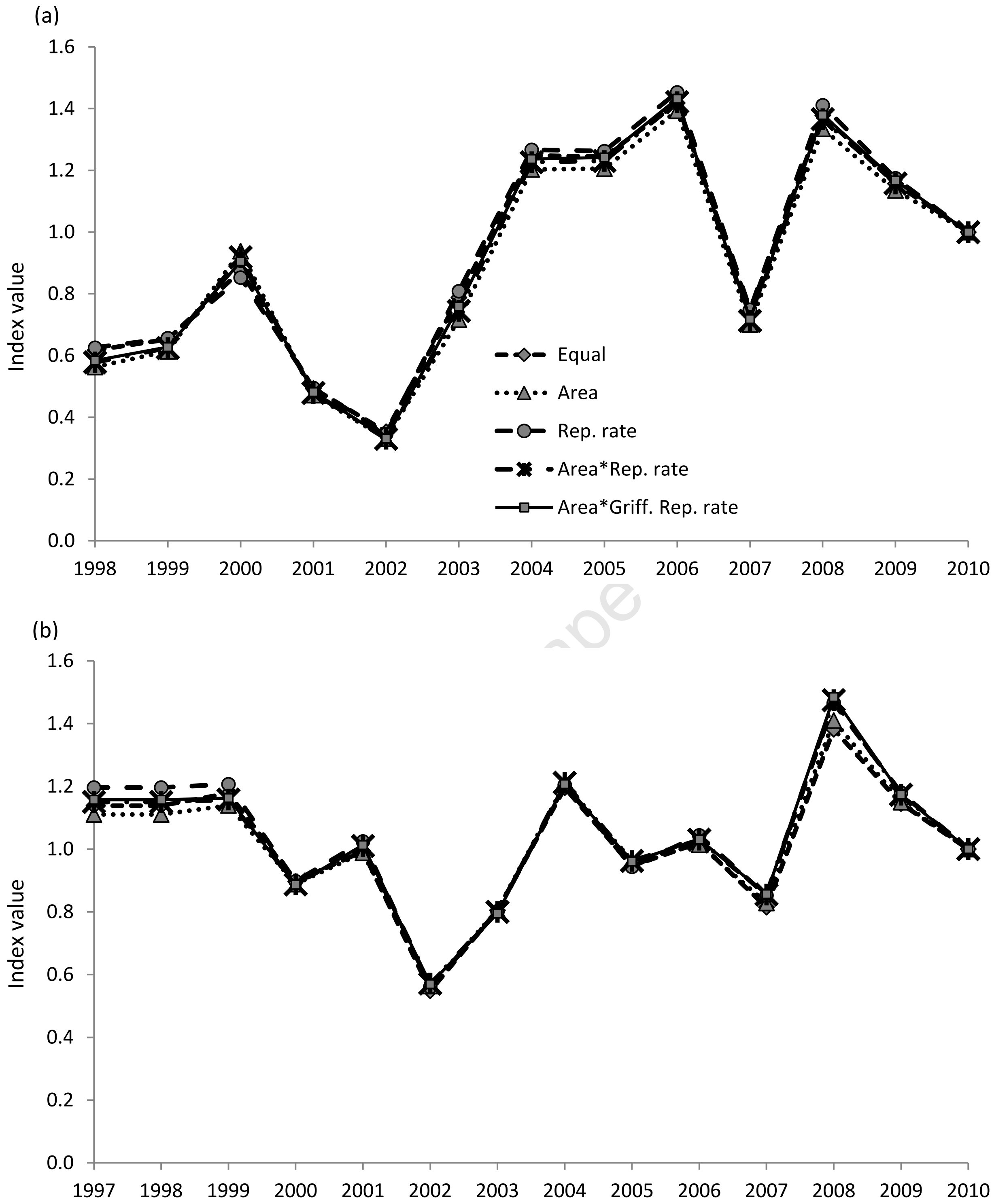

Figure 9: National indices for Northern Black Korhaans for (a) summer and (b) winter. Indices were derived by multiplying precinct-specific bird densities (birds/100 km) obtained from CAR count data (see text) with five different sets of weightings, each one represented by one set of points and a line. “Str ave” had equal weightings for each precinct. “Area wt” had precincts weighted by their relative area, and “rr wt” had precincts weighted by SABAP1 reporting rates for Northern Black Korhaans for that precinct. “Area*rr” weights used area and reporting rate multiplied together, and “area*Grr wt” used area multiplied by the logarithmic conversion of reporting rates proposed by Griffioen (2001).

Appendix 4. Supplementary data for Chapter 6

Table A4.1: Results of population trend analysis of CAR project data for (a) Blue Korhaans, (b) Karoo Korhaans and (c) Northern Black Korhaans for all precincts in which the number of birds recorded attained the criteria for inclusion (see text). "Birds/100 km" columns show the count totals estimated using the Underhill index, converted to birds per 100 km of road surveyed; "incr" columns show the percent change in population per year, calculated as the slope of the weighted linear regressions; "Δ incr" columns show the change in increment from one year to the next (see text). At inflection points the Δ incr values change from negative to positive or vice versa. R^2 values give the proportion of the variance of the totals that is explained by the trend line; SD is the standard deviation of the totals, CV is the coefficient of variation, and "% imp" values indicate the percentage of the overall total that was imputed using the Underhill index. Distance gives the distance in kilometres of the routes included in each analysis. For uniformity, all results are presented to two decimal places.

(a)

	Eastern Karoo					
Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1997				1.85	0.14	
1998				4.44	0.03	–0.11
1999	6.25	–0.20		3.40	–0.07	–0.10
2000	1.08	–0.18	0.03	6.21	–0.14	–0.07
2001	5.72	–0.16	0.02	5.46	–0.16	–0.02
2002	1.26	–0.14	0.02	0.28	–0.14	0.02
2003	2.81	–0.12	0.02	3.68	–0.09	0.05
2004	0.61	–0.09	0.03	1.56	–0.07	0.02
2005	1.74	–0.08	0.02	1.44	–0.10	–0.03
2006	2.15	–0.06	0.01	3.85	–0.18	–0.08
2007	1.94	–0.04	0.02	1.13	–0.25	–0.08
2008	0.13	0.02	0.06	1.50	–0.30	–0.05
2009	2.80	0.12	0.10	0.00	–0.30	0.00
2010	2.35	0.25	0.13	1.18	–0.24	0.06
Mean	2.40	–0.06		2.57	–0.13	
R^2	0.22			0.37		
SD	1.87			1.93		
CV	77.63			75.12		
% imp	24.88			25.70		
Distance (km)	877.24			706.07		

Mpumalanga

Year	Winter		
	birds/100 km	incr	Δ incr
2003	1.60	0.30	
2004	2.09	0.25	–0.05
2005	2.73	0.19	–0.06
2006	6.54	0.12	–0.07
2007	4.00	0.06	–0.06
2008	3.09	0.01	–0.05
2009	5.02	–0.03	–0.04
2010	2.73	–0.07	–0.03
Mean	3.48	0.10	
R^2	0.57		
SD	1.64		
CV	47.10		
% imp	9.77		
Distance (km)	550.09		

North-eastern Eastern Cape

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
2001	5.38	0.05		7.49	–0.06	
2002	6.53	0.04	–0.01	10.01	–0.05	0.00
2003	5.25	0.03	–0.01	5.68	–0.04	0.01
2004	7.96	0.01	–0.01	7.32	–0.02	0.02
2005	6.99	0.00	–0.01	5.95	0.00	0.02
2006	5.82	–0.01	–0.01	6.71	0.02	0.02
2007	6.21	–0.01	0.00	7.36	0.05	0.03
2008	5.62	0.00	0.00	5.60	0.07	0.02
2009	8.39	–0.01	0.00	11.35	0.09	0.02
2010	5.21	–0.02	–0.01	8.73	0.10	0.01
Mean	6.34	0.01		7.62	0.02	
R^2	0.13			0.30		
SD	1.13			1.90		
CV	17.83			24.96		
% imp	25.67			18.22		
Distance (km)	876.77			929.18		

North-eastern Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1999				4.36	–0.06	
2000				5.77	–0.04	0.02
2001	2.12	–0.06		3.26	–0.01	0.02
2002	1.93	–0.03	0.03	2.74	0.00	0.01
2003	1.09	0.01	0.04	5.19	–0.01	–0.01
2004	2.32	0.05	0.04	5.60	–0.03	–0.02
2005	1.08	0.08	0.03	3.59	–0.04	–0.02
2006	2.54	0.10	0.02	5.68	–0.03	0.02
2007	2.40	0.11	0.01	0.98	0.03	0.05
2008	2.52	0.11	0.00	3.90	0.11	0.08
2009	2.26	0.11	0.00	7.31	0.19	0.08
2010	3.64	0.13	0.01	5.93	0.26	0.06
Mean	2.19	0.06		4.52	0.03	
R^2	0.45			0.18		
SD	0.74			1.73		
CV	33.75			38.21		
% imp	17.45			25.65		
Distance (km)	1630.85			1692.03		

North-western Free State

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1999				0.45	0.12	
2000	0.93	–0.08		0.29	0.31	0.19
2001	0.34	0.03	0.11	0.00	0.46	0.16
2002	0.24	0.14	0.11	1.26	0.52	0.06
2003	0.57	0.24	0.09	1.03	0.45	–0.07
2004	0.62	0.29	0.06	1.59	0.29	–0.16
2005	0.93	0.30	0.00	3.26	0.11	–0.18
2006	1.86	0.25	–0.05	1.94	–0.02	–0.13
2007	1.88	0.17	–0.08	0.91	–0.09	–0.07
2008	2.17	0.09	–0.08	1.17	–0.10	–0.01
2009	1.41	0.03	–0.06	0.72	–0.07	0.03
2010	1.57	–0.02	–0.05	1.58	–0.01	0.06
Mean	1.14	0.13		1.18	0.16	
R^2	0.78			0.51		
SD	0.67			0.87		
CV	58.98			73.20		
% imp	14.12			14.08		
Distance (km)	965.95			1270.06		

Southern Free State

Year	Summer birds/100 km	Summer incr	Summer Δ incr	Winter birds/100 km	Winter incr	Winter Δ incr
1998	4.94	0.01				
1999	7.17	0.01	0.00	6.80	0.06	
2000	3.88	0.01	0.00	8.16	0.04	–0.02
2001	6.85	0.01	0.00	12.90	0.03	–0.01
2002	5.15	0.01	0.00	5.63	0.03	0.00
2003	5.53	0.01	0.00	9.29	0.05	0.01
2004	6.40	0.02	0.00	9.78	0.06	0.01
2005	5.45	0.03	0.01	9.28	0.07	0.01
2006	5.08	0.04	0.01	10.66	0.06	–0.01
2007	7.37	0.04	0.01	15.30	0.03	–0.02
2008	6.17	0.04	0.00	12.56	0.00	–0.03
2009	8.43	0.03	–0.01	9.58	–0.03	–0.03
2010	5.84	0.01	–0.02	10.37	–0.05	–0.02
Mean	6.02	0.02		10.02	0.03	
R^2	0.20			0.38		
SD	1.22			2.66		
CV	20.22			26.49		
% imp	25.10			21.12		
Distance (km)	5052.35			4511.04		

Year	Wakkerstroom Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
2000	2.98	–0.08		5.09	–0.05	
2001	3.44	–0.16	–0.08	5.15	–0.01	0.04
2002	5.05	–0.23	–0.07	3.21	0.03	0.04
2003	3.21	–0.28	–0.05	4.29	0.06	0.03
2004	1.61	–0.29	–0.01	2.95	0.05	–0.01
2005	1.38	–0.26	0.03	10.45	0.00	–0.05
2006	0.00	–0.18	0.08	8.65	–0.06	–0.06
2007	3.05	–0.05	0.13	7.86	–0.09	–0.03
2008	0.00	0.12	0.17	0.39	–0.06	0.03
2009	1.52	0.32	0.20	5.90	0.04	0.10
2010	3.05	0.54	0.22	9.04	0.20	0.16
Mean	2.30	–0.05		5.72	0.01	
R^2	0.39			0.12		
SD	1.54			3.03		
CV	67.10			52.89		
% imp	7.43			17.04		
Distance (km)	435.65			373.25		

(b)

Year	Beaufort West Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1999				23.06	0.09	
2000	26.99	–0.04		21.84	0.10	0.01
2001	24.99	–0.05	–0.01	25.49	0.10	0.00
2002	35.98	–0.05	0.00	21.84	0.07	–0.02
2003	24.99	–0.03	0.02	55.83	0.04	–0.03
2004	11.69	0.01	0.04	30.05	0.01	–0.03
2005	22.54	0.05	0.03	35.89	0.01	–0.01
2006	40.50	0.06	0.01	20.03	0.03	0.02
2007	32.55	0.06	0.00	23.37	0.06	0.03
2008	17.53	0.05	0.00	66.77	0.09	0.03
2009	40.07	0.06	0.00	30.88	0.10	0.01
2010	32.55	0.07	0.01	44.24	0.09	–0.01
Mean	28.21	0.02		33.28	0.06	
R^2	0.15			0.27		
SD	9.12			15.00		
CV	32.31			45.07		
% imp	16.90			11.58		
Distance (km)	119.81			119.81		

Eastern Cape Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				4.80	0.04	
1999	2.30	0.01		3.19	0.00	–0.03
2000	6.39	–0.02	–0.03	8.60	–0.02	–0.02
2001	3.73	–0.03	–0.01	6.72	–0.02	0.00
2002	2.17	–0.02	0.01	2.13	0.00	0.03
2003	3.02	0.01	0.02	4.48	0.05	0.04
2004	4.43	0.02	0.02	4.44	0.09	0.04
2005	2.58	0.03	0.01	6.06	0.10	0.01
2006	3.76	0.03	0.00	9.02	0.09	–0.01
2007	5.92	0.02	–0.01	4.94	0.06	–0.02
2008	2.21	0.01	–0.01	8.43	0.04	–0.02
2009	4.69	0.01	0.00	6.98	0.03	–0.02
2010	3.73	0.01	0.00	6.85	0.01	–0.01
Mean	3.75	0.01		5.89	0.03	
R^2	0.06			0.27		
SD	1.41			2.12		
CV	37.63			36.00		
% imp	14.45			11.19		
Distance (km)	1063.45			1154.95		

Eastern Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1996	1.55	0.20				
1997	3.00	0.12	–0.07	0.52	0.52	
1998	4.96	0.07	–0.06	1.18	0.35	–0.16
1999	2.47	0.03	–0.04	2.87	0.20	–0.16
2000	3.21	0.00	–0.02	3.49	0.07	–0.12
2001	4.75	0.00	–0.01	3.76	0.00	–0.07
2002	1.91	0.00	0.01	1.08	–0.01	–0.01
2003	3.61	0.02	0.01	1.42	0.01	0.03
2004	2.81	0.02	0.01	2.27	0.04	0.02
2005	5.15	0.02	–0.01	3.13	0.03	–0.01
2006	2.14	0.00	–0.02	2.65	–0.01	–0.04
2007	6.33	–0.03	–0.03	2.83	–0.04	–0.04
2008	2.04	–0.07	–0.04	1.85	–0.05	–0.01
2009				0.93	–0.03	0.03
2010				3.71	0.03	0.06
Mean	3.38	0.03		2.26	0.08	
R^2	0.19			0.43		
SD	1.48			1.10		
CV	43.89			48.53		
% imp	22.32			18.22		
Distance (km)	1115.38			706.07		

Year	Overberg Summer birds/100 km	incr	Δ incr	Winter birds/100 km	incr	Δ incr
1997	0.57	0.18		1.73	0.12	
1998	1.11	0.14	–0.04	2.39	0.07	–0.05
1999	0.89	0.11	–0.03	2.33	0.03	–0.04
2000	1.50	0.08	–0.03	4.44	–0.01	–0.03
2001	1.00	0.06	–0.02	2.05	–0.02	–0.01
2002	1.22	0.04	–0.02	1.76	0.00	0.02
2003	1.61	0.03	–0.02	2.62	0.03	0.03
2004	1.33	0.01	–0.02	1.82	0.06	0.03
2005	1.27	–0.02	–0.02	3.41	0.08	0.01
2006	1.16	–0.04	–0.02	3.59	0.07	–0.01
2007	2.38	–0.05	–0.01	2.79	0.04	–0.02
2008	0.56	–0.05	0.00	3.76	0.02	–0.03
2009	1.00	–0.02	0.02	3.53	–0.01	–0.03
2010	1.50	0.02	0.04	2.67	–0.03	–0.03
Mean	1.22	0.04		2.78	0.03	
R^2	0.30			0.37		
SD	0.46			0.85		
CV	37.74			30.42		
% imp	0.12			0.07		
Distance (km)	1805.97			1757.19		

(c)

Year	Eastern Cape Karoo Summer birds/100 km	incr	Δ incr	Winter birds/100 km	incr	Δ incr
1999				4.76	–0.07	
2000	13.98	–0.12		3.66	–0.03	0.03
2001	7.28	–0.06	0.06	3.48	–0.01	0.03
2002	6.12	–0.01	0.05	2.42	0.01	0.01
2003	6.22	0.02	0.04	5.02	0.00	–0.01
2004	11.57	0.03	0.01	5.92	–0.03	–0.02
2005	8.65	0.02	–0.01	2.38	–0.05	–0.02
2006	8.93	0.00	–0.02	4.17	–0.06	–0.01
2007	10.57	–0.02	–0.02	3.20	–0.05	0.01
2008	8.46	–0.03	–0.01	1.65	–0.03	0.02
2009	6.22	–0.03	0.00	5.02	0.00	0.02
2010	9.40	–0.02	0.01	2.77	0.02	0.02
Mean	8.85	–0.02		3.71	–0.02	
R^2	0.30			0.13		
SD	2.47			1.30		
CV	27.87			35.01		
% imp	14.95			14.70		
Distance (km)	1063.45			1154.95		

Eastern Karoo

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1999				26.73	–0.27	
2000				12.63	–0.22	0.04
2001	5.21	0.53		16.36	–0.16	0.06
2002	4.03	0.48	–0.05	3.76	–0.09	0.07
2003	15.78	0.40	–0.09	8.50	–0.02	0.08
2004	25.82	0.29	–0.11	11.62	0.05	0.06
2005	22.02	0.18	–0.11	6.37	0.09	0.04
2006	44.71	0.10	–0.08	16.00	0.11	0.02
2007	12.62	0.05	–0.05	10.20	0.10	–0.01
2008	39.54	0.03	–0.02	18.56	0.08	–0.02
2009	18.70	0.03	0.00	15.95	0.05	–0.03
2010	31.61	0.04	0.01	11.78	0.01	–0.04
Mean	22.00	0.21		13.20	–0.02	
R^2	0.66			0.44		
SD	13.63			6.10		
CV	61.94			46.18		
% imp	23.58			24.10		
Distance (km)	911.05			706.07		

North-eastern Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1998				2.19	0.02	
1999				4.02	–0.01	–0.04
2000				3.87	–0.03	–0.01
2001	2.63	0.26		2.87	–0.01	0.01
2002	3.16	0.21	–0.05	1.49	0.01	0.02
2003	5.48	0.15	–0.06	3.09	0.02	0.01
2004	6.58	0.09	–0.06	4.17	0.01	–0.02
2005	7.05	0.04	–0.05	4.36	–0.03	–0.03
2006	5.58	0.01	–0.03	3.19	–0.05	–0.02
2007	4.38	0.00	–0.01	1.39	–0.03	0.02
2008	6.58	0.00	0.00	2.33	0.02	0.05
2009	6.34	0.00	0.00	2.90	0.10	0.07
2010	5.16	–0.01	–0.01	4.62	0.18	0.08
Mean	5.29	0.08		3.11	0.02	
R^2	0.70			0.21		
SD	1.50			1.06		
CV	28.25			34.11		
% imp	3.67			24.65		
Distance (km)	1789.85			1789.85		

North-western Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1999				19.25	0.03	
2000	35.12	0.06		21.53	0.04	0.00
2001	26.44	0.12	0.06	23.49	0.05	0.01
2002	17.13	0.15	0.03	17.83	0.06	0.01
2003	44.66	0.15	0.00	20.80	0.06	0.00
2004	58.47	0.11	–0.04	33.88	0.06	–0.01
2005	63.98	0.06	–0.05	30.87	0.04	–0.01
2006	50.92	0.01	–0.05	24.07	0.03	–0.01
2007	36.05	–0.02	–0.03	23.10	0.03	0.00
2008	56.22	–0.04	–0.02	41.71	0.03	0.00
2009	61.51	–0.07	–0.03	29.36	0.01	–0.01
2010	27.35	–0.11	–0.04	27.33	0.00	–0.02
Mean	43.44	0.04		26.10	0.04	
R^2	0.43			0.44		
SD	16.00			6.90		
CV	36.82			26.42		
% imp	16.18			22.82		
Distance (km)	965.95			1270.06		

Southern Free State

Year	Summer			Winter		
	birds/100 km	incr	Δ incr	birds/100 km	incr	Δ incr
1997				11.01	0.15	
1998	17.44	0.06		22.07	0.08	–0.07
1999	21.67	0.02	–0.04	24.49	0.02	–0.06
2000	48.52	0.01	–0.01	20.37	–0.01	–0.04
2001	17.86	0.04	0.03	30.69	–0.02	–0.01
2002	12.14	0.09	0.05	8.12	0.01	0.02
2003	22.81	0.14	0.05	19.22	0.04	0.04
2004	47.99	0.15	0.01	21.75	0.07	0.03
2005	48.21	0.12	–0.03	28.71	0.07	0.00
2006	60.77	0.07	–0.05	22.07	0.06	–0.01
2007	25.93	0.04	–0.03	23.33	0.04	–0.02
2008	55.31	0.03	–0.01	35.34	0.02	–0.02
2009	46.66	0.03	0.00	23.30	0.00	–0.02
2010	46.97	0.03	0.00	24.71	–0.01	–0.02
Mean	36.33	0.06		22.51	0.04	
R^2	0.46			0.32		
SD	16.81			6.99		
CV	46.28			31.06		
% imp	20.18			22.62		
Distance (km)	5052.35			4511.04		

Table A4.2: Habitat selection by (a) Blue Korhaans (BKs), (b) Karoo Korhaans (KKs) and (c) Northern Black Korhaans (NBKs) using Coordinated Avifaunal Roadcounts (CAR) data, separated by precinct (Figure 1 in Chapter 1). "Land area" sections give the percentage of each type of land cover (natural or transformed) within a 2 000 m wide buffer zone around each route, as calculated from the National Land-Cover maps for 1994, 2000 and 2009 (NLC1994, NLC2000 and NLC2009 respectively). "No. BKs/KKs/NBKs" columns give numbers of birds seen in each habitat type on these routes over the whole count period (1993–2010). The "Jacobs index" section gives the values calculated for this index; *r* is the proportion of birds seen in natural habitat to the total number of birds seen on that route, *p* is the proportion of the area of natural habitat to the total land area, calculated as the average of the three NLC values, and *D* is the index, calculated using the formula presented in Jacobs (1974). Positive values for *D* indicate selection for natural habitat, negative the reverse. The bottom row contains the overall percentages of each habitat type for each map, the percentage of birds seen in each habitat type, the total number of birds on which the analysis is based (underlined), and the Jacobs index for the whole precinct (excluding routes on which the species was never seen).

(a)

Eastern Cape Karoo summer

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EM01	95.20	4.80	97.94	2.06	2	0	**2**	1.00	0.97	**1.00**
EM02	92.54	7.46	97.85	2.15	3	2	**5**	0.60	0.95	**–0.86**
EP06	70.40	29.60	82.60	17.40	1	12	**13**	0.08	0.77	**–0.95**
EP07	92.19	7.81	97.38	2.62	17	0	**17**	1.00	0.95	**1.00**
EP10	76.55	23.45	96.47	3.53	2	0	**2**	1.00	0.87	**1.00**
Overall	**86.39**	**13.61**	**94.73**	**5.27**	**64.10**	**35.90**	**<u>39</u>**	**0.64**	**0.91**	**–0.69**

Eastern Cape Karoo winter

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EM01	95.20	4.80	97.94	2.06	5	0	**5**	1.00	0.97	**1.00**
EP06	70.40	29.60	82.60	17.40	5	13	**18**	0.28	0.77	**–0.79**
EP07	92.19	7.81	97.38	2.62	16	0	**16**	1.00	0.95	**1.00**
EP10	76.55	23.45	96.47	3.53	3	0	**3**	1.00	0.87	**1.00**
ES04	97.38	2.62	97.41	2.59	0	3	**3**	0.00	0.97	**–1.00**
Overall	**87.05**	**12.95**	**94.56**	**5.44**	**64.44**	**35.56**	**<u>45</u>**	**0.64**	**0.91**	**–0.69**

	Eastern Karoo summer									
	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
NK013	99.19	0.81	100.00	0.00	0	2	**2**	0.00	1.00	**–1.00**
NK032	98.40	1.60	100.00	0.00	8	0	**8**	1.00	0.99	**1.00**
NK042	97.91	2.09	100.00	0.00	3	0	**3**	1.00	0.99	**1.00**
NK043	99.64	0.36	100.00	0.00	5	0	**5**	1.00	1.00	**1.00**
NK044	99.83	0.17	100.00	0.00	15	0	**15**	1.00	1.00	**1.00**
NK051	99.95	0.05	99.98	0.02	4	0	**4**	1.00	1.00	**1.00**
NK061	99.96	0.04	100.00	0.00	38	0	**38**	1.00	1.00	**1.00**
NK063	99.84	0.16	100.00	0.00	10	0	**10**	1.00	1.00	**1.00**
NK073	99.38	0.62	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK093	87.74	12.26	100.00	0.00	5	0	**5**	1.00	0.94	**1.00**
NK101	97.76	2.24	97.91	2.09	17	16	**33**	0.52	0.98	**–0.95**
NK102	99.70	0.30	99.69	0.31	5	0	**5**	1.00	1.00	**1.00**
NK142	99.33	0.67	99.74	0.26	29	0	**29**	1.00	1.00	**1.00**
NK162	98.57	1.43	100.00	0.00	9	0	**9**	1.00	0.99	**1.00**
NK181	98.19	1.81	98.70	1.30	4	6	**10**	0.40	0.98	**–0.98**
NK182	94.73	5.27	96.73	3.27	13	0	**13**	1.00	0.96	**1.00**
NK183	96.15	3.85	96.71	3.29	4	0	**4**	1.00	0.96	**1.00**
NK311	99.04	0.96	100.00	0.00	6	3	**9**	0.67	1.00	**–0.98**
NK312	97.95	2.05	99.94	0.06	1	0	**1**	1.00	0.99	**1.00**
NK323	96.11	3.89	99.97	0.03	7	0	**7**	1.00	0.98	**1.00**
NK331	97.41	2.59	98.95	1.05	26	0	**26**	1.00	0.98	**1.00**
NK332	94.14	5.86	100.00	0.00	13	0	**13**	1.00	0.97	**1.00**
NK333	99.82	0.18	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK341	99.29	0.71	99.31	0.69	12	4	**16**	0.75	0.99	**–0.96**
NK351	99.82	0.18	99.97	0.03	3	0	**3**	1.00	1.00	**1.00**
NK353	99.96	0.04	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK361	97.27	2.73	100.00	0.00	5	0	**5**	1.00	0.99	**1.00**
NK363	99.39	0.61	100.00	0.00	10	0	**10**	1.00	1.00	**1.00**
NK391	83.63	16.37	99.93	0.07	3	0	**3**	1.00	0.92	**1.00**
NK392	87.45	12.55	96.61	3.39	1	0	**1**	1.00	0.92	**1.00**
NK431	99.14	0.86	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
Overall	**97.23**	**2.77**	**99.44**	**0.56**	**89.80**	**10.20**	**304**	**0.90**	**0.98**	**–0.74**

Eastern Karoo winter

Route	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK032	98.40	1.60	100.00	0.00	4	0	**4**	1.00	0.99	**1.00**
NK041	98.71	1.29	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK042	97.91	2.09	100.00	0.00	4	0	**4**	1.00	0.99	**1.00**
NK044	99.83	0.17	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK061	99.96	0.04	100.00	0.00	33	0	**33**	1.00	1.00	**1.00**
NK063	99.84	0.16	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK101	97.76	2.24	97.91	2.09	8	3	**11**	0.73	0.98	**–0.89**
NK102	99.70	0.30	99.69	0.31	11	0	**11**	1.00	1.00	**1.00**
NK113	99.04	0.96	100.00	0.00	1	0	**1**	1.00	1.00	**1.00**
NK142	99.33	0.67	99.74	0.26	11	0	**11**	1.00	1.00	**1.00**
NK181	98.19	1.81	98.70	1.30	1	0	**1**	1.00	0.98	**1.00**
NK182	94.73	5.27	96.73	3.27	26	0	**26**	1.00	0.96	**1.00**
NK183	96.15	3.85	96.71	3.29	7	0	**7**	1.00	0.96	**1.00**
NK211	92.28	7.72	100.00	0.00	1	0	**1**	1.00	0.96	**1.00**
NK311	99.04	0.96	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK312	97.95	2.05	99.94	0.06	11	0	**11**	1.00	0.99	**1.00**
NK323	96.11	3.89	99.97	0.03	2	0	**2**	1.00	0.98	**1.00**
NK331	97.41	2.59	98.95	1.05	10	0	**10**	1.00	0.98	**1.00**
NK332	94.14	5.86	100.00	0.00	2	0	**2**	1.00	0.97	**1.00**
NK341	99.29	0.71	99.31	0.69	23	0	**23**	1.00	0.99	**1.00**
NK342	98.39	1.61	98.29	1.71	3	2	**5**	0.60	0.98	**–0.95**
NK343	98.62	1.38	98.58	1.42	7	0	**7**	1.00	0.99	**1.00**
NK351	99.82	0.18	99.97	0.03	5	0	**5**	1.00	1.00	**1.00**
NK353	99.96	0.04	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK362	97.45	2.55	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK363	99.39	0.61	100.00	0.00	8	0	**8**	1.00	1.00	**1.00**
NK372	99.79	0.21	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK391	83.63	16.37	99.93	0.07	5	0	**5**	1.00	0.92	**1.00**
NK431	99.14	0.86	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
Overall	**99.42**	**0.58**	**97.59**	**2.41**	**97.64**	**2.36**	**212**	**0.98**	**0.99**	**–0.23**

Mpumalanga summer

Route	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
MC01	76.25	23.75	63.54	36.46	6	0	**6**	1.00	0.70	**1.00**
MC02	82.21	17.79	78.60	21.40	4	6	**10**	0.40	0.80	**–0.72**
MC03	79.85	20.15	74.29	25.71	2	0	**2**	1.00	0.77	**1.00**
MC05	76.55	23.45	67.00	33.00	0	3	**3**	0.00	0.72	**–1.00**
MC06	85.01	14.99	80.55	19.45	2	0	**2**	1.00	0.83	**1.00**
MT01	75.80	24.20	68.10	31.90	18	0	**18**	1.00	0.72	**1.00**
MT02	52.67	47.33	42.65	57.35	9	0	**9**	1.00	0.48	**1.00**
MT03	67.93	32.07	51.38	48.62	4	0	**4**	1.00	0.60	**1.00**
MT05	74.10	25.90	59.52	40.48	20	0	**20**	1.00	0.67	**1.00**
Overall	**75.06**	**24.94**	**66.00**	**34.00**	**87.84**	**12.16**	**74**	**0.88**	**0.71**	**0.50**

Mpumalanga winter

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
MC01	76.25	23.75	63.54	36.46	26	20	**46**	0.57	0.70	**–0.28**
MC03	79.85	20.15	74.29	25.71	0	4	**4**	0.00	0.77	**–1.00**
MC04	81.67	18.33	74.22	25.78	3	0	**3**	1.00	0.78	**1.00**
MC05	76.55	23.45	67.00	33.00	0	3	**3**	0.00	0.72	**–1.00**
MC06	85.01	14.99	80.55	19.45	16	3	**19**	0.84	0.83	**0.05**
MC07	69.89	30.11	57.94	42.06	9	5	**14**	0.64	0.64	**0.01**
MT01	75.80	24.20	68.10	31.90	49	3	**52**	0.94	0.72	**0.73**
MT02	52.67	47.33	42.65	57.35	11	0	**11**	1.00	0.48	**1.00**
MT05	74.10	25.90	59.52	40.48	14	5	**19**	0.74	0.67	**0.16**
Overall	**74.84**	**25.16**	**65.46**	**34.54**	**74.85**	**25.15**	**171**	**0.75**	**0.70**	**0.12**

North-eastern Eastern Cape summer

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EE07	84.18	15.82	77.99	22.01	1	0	**1**	1.00	0.81	**1.00**
EE08	77.31	22.69	73.16	26.84	3	0	**3**	1.00	0.75	**1.00**
EE11	92.61	7.39	89.51	10.49	7	2	**9**	0.78	0.91	**–0.49**
EE12	82.64	17.36	78.23	21.77	2	0	**2**	1.00	0.80	**1.00**
EE14	82.86	17.14	74.87	25.13	9	5	**14**	0.64	0.79	**–0.35**
EE15	81.65	18.35	81.07	18.93	28	21	**49**	0.57	0.81	**–0.53**
EE18	86.31	13.69	74.45	25.55	30	8	**38**	0.79	0.80	**–0.04**
EE19	84.69	15.31	84.68	15.32	201	74	**275**	0.73	0.85	**–0.34**
EQ01	54.74	45.26	49.70	50.30	43	4	**47**	0.91	0.52	**0.82**
EQ02	46.17	53.83	39.72	60.28	27	5	**32**	0.84	0.43	**0.76**
Overall	**77.70**	**22.30**	**73.37**	**26.63**	**74.68**	**25.32**	**470**	**0.75**	**0.76**	**–0.02**

North-eastern Eastern Cape winter

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EB03	81.64	18.36	75.27	24.73	2	0	**2**	1.00	0.78	**1.00**
EE09	79.20	20.80	82.11	17.89	0	3	**3**	0.00	0.81	**–1.00**
EE10	84.02	15.98	79.98	20.02	3	0	**3**	1.00	0.82	**1.00**
EE11	92.61	7.39	89.51	10.49	4	0	**4**	1.00	0.91	**1.00**
EE12	82.64	17.36	78.23	21.77	8	16	**24**	0.33	0.80	**–0.78**
EE14	82.86	17.14	74.87	25.13	25	15	**40**	0.63	0.79	**–0.38**
EE15	81.65	18.35	81.07	18.93	13	13	**26**	0.50	0.81	**–0.63**
EE18	86.31	13.69	74.45	25.55	27	14	**41**	0.66	0.80	**–0.36**
EE19	84.69	15.31	84.68	15.32	148	260	**408**	0.36	0.85	**–0.81**
EQ01	54.74	45.26	49.70	50.30	62	16	**78**	0.79	0.52	**0.56**
EQ02	46.17	53.83	39.72	60.28	77	17	**94**	0.82	0.43	**0.72**
Overall	**78.39**	**21.61**	**74.75**	**25.25**	**51.04**	**48.96**	**723**	**0.51**	**0.77**	**–0.52**

North-eastern Free State summer

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
FN04	68.43	31.57	55.68	44.32	2	0	**2**	1.00	0.62	**1.00**
FN11	60.11	39.89	48.52	51.48	6	0	**6**	1.00	0.54	**1.00**
FN14	70.83	29.17	60.66	39.34	2	0	**2**	1.00	0.66	**1.00**
FN16	59.72	40.28	46.60	53.40	71	2	**73**	0.97	0.53	**0.94**
FN17	78.04	21.96	67.87	32.13	5	2	**7**	0.71	0.73	**–0.04**
FN18	86.66	13.34	80.13	19.87	3	0	**3**	1.00	0.83	**1.00**
FN21	85.70	14.30	78.74	21.26	5	0	**5**	1.00	0.82	**1.00**
FN22	82.16	17.84	72.26	27.74	2	0	**2**	1.00	0.77	**1.00**
FN23	77.42	22.58	69.12	30.88	0	2	**2**	0.00	0.73	**–1.00**
FN25	84.78	15.22	72.42	27.58	10	4	**14**	0.71	0.79	**–0.19**
FN27	86.17	13.83	73.11	26.89	6	6	**12**	0.50	0.80	**–0.59**
FN28	93.20	6.80	80.73	19.27	12	4	**16**	0.75	0.87	**–0.38**
FN30	96.21	3.79	88.59	11.41	1	0	**1**	1.00	0.92	**1.00**
FN31	91.50	8.50	87.14	12.86	0	3	**3**	0.00	0.89	**–1.00**
FN32	96.28	3.72	91.79	8.21	14	2	**16**	0.88	0.94	**–0.39**
FN34	55.11	44.89	39.79	60.21	0	2	**2**	0.00	0.47	**–1.00**
FN37	69.10	30.90	54.10	45.90	3	6	**9**	0.33	0.62	**–0.52**
FN39	50.88	49.12	38.22	61.78	2	1	**3**	0.67	0.45	**0.43**
FN40	43.40	56.60	29.73	70.27	3	0	**3**	1.00	0.37	**1.00**
FN41	62.46	37.54	48.34	51.66	20	2	**22**	0.91	0.55	**0.78**
FN42	70.77	29.23	57.09	42.91	35	6	**41**	0.85	0.64	**0.53**
FN44	53.80	46.20	34.68	65.32	2	0	**2**	1.00	0.44	**1.00**
FN45	83.52	16.48	78.30	21.70	20	3	**23**	0.87	0.81	**0.22**
FN48	67.34	32.66	52.70	47.30	7	0	**7**	1.00	0.60	**1.00**
FN49	88.48	11.52	74.25	25.75	12	3	**15**	0.80	0.81	**–0.04**
FN50	64.31	35.69	53.47	46.53	0	2	**2**	0.00	0.59	**–1.00**
FN52	47.70	52.30	33.37	66.63	10	0	**10**	1.00	0.41	**1.00**
FN57	77.20	22.80	67.58	32.42	7	1	**8**	0.88	0.72	**0.46**
FN58	66.11	33.66	55.60	44.40	21	9	**30**	0.70	0.61	**0.20**
FN59	86.92	13.08	79.26	20.74	3	0	**3**	1.00	0.83	**1.00**
FN60	67.90	32.10	55.79	44.21	27	0	**27**	1.00	0.62	**1.00**
Overall	**73.10**	**26.90**	**61.97**	**38.03**	**83.83**	**16.17**	**371**	**0.84**	**0.68**	**0.43**

	North-eastern Free State winter									
	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FN02	50.45	49.55	38.98	61.02	2	0	2	1.00	0.45	1.00
FN04	68.43	31.57	55.68	44.32	6	0	6	1.00	0.62	1.00
FN05	74.61	25.39	55.05	44.95	10	12	22	0.45	0.65	–0.38
FN06	63.63	36.37	48.19	51.81	3	3	6	0.50	0.56	–0.12
FN07	50.07	49.93	36.31	63.69	6	0	6	1.00	0.43	1.00
FN11	60.11	39.89	48.52	51.48	4	0	4	1.00	0.54	1.00
FN15	72.02	27.98	60.81	39.19	2	0	2	1.00	0.66	1.00
FN16	59.72	40.28	46.60	53.40	57	24	81	0.70	0.53	0.35
FN17	78.04	21.96	67.87	32.13	0	8	8	0.00	0.73	–1.00
FN18	86.66	13.34	80.13	19.87	18	0	18	1.00	0.83	1.00
FN19	86.31	13.69	77.45	22.55	4	5	9	0.44	0.82	–0.70
FN21	85.70	14.30	78.74	21.26	17	2	19	0.89	0.82	0.30
FN22	82.16	17.84	72.26	27.74	3	0	3	1.00	0.77	1.00
FN23	77.42	22.58	69.12	30.88	4	0	4	1.00	0.73	1.00
FN24	75.87	24.13	59.77	40.23	15	3	18	0.83	0.68	0.41
FN25	84.78	15.22	72.42	27.58	48	22	70	0.69	0.79	–0.25
FN27	86.17	13.83	73.11	26.89	32	15	47	0.68	0.80	–0.29
FN28	93.20	6.80	80.73	19.27	44	16	60	0.73	0.87	–0.42
FN29	92.42	7.58	85.14	14.86	6	13	19	0.32	0.89	–0.89
FN30	96.21	3.79	88.59	11.41	2	8	10	0.20	0.92	–0.96
FN31	91.50	8.50	87.14	12.86	5	10	15	0.33	0.89	–0.89
FN32	96.28	3.72	91.79	8.21	15	4	19	0.79	0.94	–0.62
FN37	69.10	30.90	54.10	45.90	10	15	25	0.40	0.62	–0.41
FN40	43.40	56.60	29.73	70.27	3	9	12	0.25	0.37	–0.27
FN41	62.46	37.54	48.34	51.66	27	36	63	0.43	0.55	–0.25
FN42	70.77	29.23	57.09	42.91	69	14	83	0.83	0.64	0.47
FN43	95.83	4.17	87.03	12.97	7	0	7	1.00	0.91	1.00
FN44	53.80	46.20	34.68	65.32	8	2	10	0.80	0.44	0.67
FN45	83.52	16.48	78.30	21.70	22	0	22	1.00	0.81	1.00
FN46	75.26	24.74	55.53	44.47	23	13	36	0.64	0.65	–0.03
FN49	88.48	11.52	74.25	25.75	54	49	103	0.52	0.81	–0.60
FN50	64.31	35.69	53.47	46.53	0	4	4	0.00	0.59	–1.00
FN52	47.70	52.30	33.37	66.63	11	4	15	0.73	0.41	0.60
FN53	79.75	20.25	70.31	29.69	4	0	4	1.00	0.75	1.00
FN55	82.87	17.13	72.47	27.53	2	2	4	0.50	0.78	–0.55
FN56	57.68	42.32	45.86	54.14	2	1	3	0.67	0.52	0.30
FN57	77.20	22.80	67.58	32.42	12	8	20	0.60	0.72	–0.27
FN58	66.11	33.66	55.60	44.40	30	18	48	0.63	0.61	0.03
FN59	86.92	13.08	79.26	20.74	2	0	2	1.00	0.83	1.00
FN60	67.90	32.10	55.79	44.21	39	0	39	1.00	0.62	1.00
FN61	57.15	42.85	40.73	59.27	6	1	7	0.86	0.49	0.72
Overall	74.18	25.82	62.61	37.39	66.39	33.61	955	0.66	0.68	–0.05

North-western Free State summer

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FW02	53.03	46.97	42.02	57.98	1	0	1	1.00	0.48	1.00
FW04	60.38	39.62	46.07	53.93	9	0	9	1.00	0.53	1.00
FW18	85.16	14.84	73.59	26.41	15	0	15	1.00	0.79	1.00
FW19	48.94	51.06	31.43	68.57	1	4	5	0.20	0.40	–0.46
FW22	83.66	16.34	68.90	31.10	6	0	6	1.00	0.76	1.00
FW23	66.61	33.39	53.98	46.02	4	0	4	1.00	0.60	1.00
FW26	72.40	27.60	51.09	48.91	3	0	3	1.00	0.62	1.00
FW31	77.26	22.74	52.58	47.42	0	4	4	0.00	0.65	–1.00
FW34	68.72	31.28	47.41	52.59	3	0	3	1.00	0.58	1.00
FW36	50.51	49.49	36.57	63.43	8	0	8	1.00	0.44	1.00
FW40	37.86	62.14	15.82	84.18	1	0	1	1.00	0.27	1.00
FW46	90.77	9.23	77.68	22.32	32	0	32	1.00	0.84	1.00
FW47	89.03	10.97	69.47	30.53	10	0	10	1.00	0.79	1.00
FW51	73.78	26.22	66.79	33.21	68	0	68	1.00	0.70	1.00
FW53	71.83	28.17	58.03	41.97	17	0	17	1.00	0.65	1.00
FW58	82.88	17.12	65.69	34.31	24	0	24	1.00	0.74	1.00
FW61	78.30	21.70	70.06	29.94	2	0	2	1.00	0.74	1.00
FW62	59.43	40.57	44.03	55.97	2	0	2	1.00	0.52	1.00
Overall	68.83	31.17	53.31	46.69	96.26	3.74	214	0.96	0.61	0.89

North-western Free State winter

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FW08	79.41	20.59	68.90	31.10	2	0	2	1.00	0.74	1.00
FW15	68.51	31.49	61.96	38.04	5	0	5	1.00	0.65	1.00
FW18	85.16	14.84	73.59	26.41	4	0	4	1.00	0.79	1.00
FW19	48.94	51.06	31.43	68.57	0	3	3	0.00	0.40	–1.00
FW34	68.72	31.28	47.41	52.59	5	0	5	1.00	0.58	1.00
FW36	50.51	49.49	36.57	63.43	3	0	3	1.00	0.44	1.00
FW46	90.77	9.23	77.68	22.32	24	0	24	1.00	0.84	1.00
FW47	89.03	10.97	69.47	30.53	18	0	18	1.00	0.79	1.00
FW51	73.78	26.22	66.79	33.21	59	0	59	1.00	0.70	1.00
FW53	71.83	28.17	58.03	41.97	11	0	11	1.00	0.65	1.00
FW58	82.88	17.12	65.69	34.31	6	0	6	1.00	0.74	1.00
FW61	78.30	21.70	70.06	29.94	4	0	4	1.00	0.74	1.00
Overall	72.60	27.40	59.08	40.92	97.92	2.08	144	0.98	0.66	0.92

Southern Free State summer

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EV01	91.35	8.65	97.92	2.08	11	0	11	1.00	0.95	1.00
FS01	90.69	9.31	91.18	8.82	4	0	4	1.00	0.91	1.00
FS02	97.80	2.20	98.35	1.65	3	0	3	1.00	0.98	1.00
FS03	98.60	1.40	98.34	1.66	7	0	7	1.00	0.98	1.00
FS04	99.38	0.62	98.38	1.62	12	0	12	1.00	0.99	1.00
FS05	99.82	0.18	99.27	0.73	4	0	4	1.00	1.00	1.00
FS06	99.72	0.28	98.50	1.50	53	3	56	0.95	0.99	–0.73
FS07	97.95	2.05	97.20	2.80	41	3	44	0.93	0.98	–0.49
FS08	97.20	2.80	97.07	2.93	26	0	26	1.00	0.97	1.00
FS09	98.20	1.80	97.81	2.19	39	0	39	1.00	0.98	1.00
FS10	94.30	5.70	95.95	4.05	26	2	28	0.93	0.95	–0.20
FS11	96.98	3.02	97.94	2.06	19	0	19	1.00	0.97	1.00
FS12	96.33	3.67	96.12	3.88	276	1	277	1.00	0.96	0.83
FS13	99.49	0.51	98.87	1.13	21	0	21	1.00	0.99	1.00
FS14	99.92	0.08	98.90	1.10	8	3	11	0.73	0.99	–0.97

FS15	99.09	0.91	99.36	0.64	1	1	**2**	0.50	0.99	**–0.98**
FS16	92.52	7.48	90.86	9.14	9	0	**9**	1.00	0.92	**1.00**
FS17	94.90	5.10	94.57	5.43	86	2	**88**	0.98	0.95	**0.41**
FS18	95.76	4.24	95.73	4.27	39	0	**39**	1.00	0.96	**1.00**
FS19	82.64	17.36	74.03	25.97	20	0	**20**	1.00	0.78	**1.00**
FS20	81.12	18.88	73.08	26.92	1	1	**2**	0.50	0.77	**–0.54**
FS23	94.58	5.42	94.45	5.55	14	0	**14**	1.00	0.95	**1.00**
FS24	96.18	3.82	97.18	2.82	2	0	**2**	1.00	0.97	**1.00**
FS25	96.69	3.31	97.70	2.30	30	6	**36**	0.83	0.97	**–0.75**
FS26	94.80	5.20	95.17	4.83	9	2	**11**	0.82	0.95	**–0.62**
FS27	97.10	2.90	97.66	2.34	55	13	**68**	0.81	0.97	**–0.80**
FS28	97.24	2.76	92.07	7.93	6	0	**6**	1.00	0.95	**1.00**
FS29	98.34	1.66	96.27	3.73	33	3	**36**	0.92	0.97	**–0.53**
FS30	78.52	21.48	72.16	27.84	36	1	**37**	0.97	0.75	**0.84**
FS31	91.10	8.90	89.07	10.93	61	18	**79**	0.77	0.90	**–0.46**
FS33	94.31	5.69	95.75	4.25	1	0	**1**	1.00	0.95	**1.00**
FS34	94.44	5.56	94.73	5.27	5	0	**5**	1.00	0.95	**1.00**
FS35	82.89	17.11	73.74	26.26	54	9	**63**	0.86	0.78	**0.25**
FS38	74.42	25.58	58.49	41.51	5	0	**5**	1.00	0.66	**1.00**
FS39	66.18	33.82	65.86	34.14	25	0	**25**	1.00	0.66	**1.00**
FS40	93.52	6.48	92.64	7.36	0	3	**3**	0.00	0.93	**–1.00**
FS42	77.79	22.21	87.50	12.50	11	0	**11**	1.00	0.83	**1.00**
FS44	90.63	9.37	81.27	18.73	5	0	**5**	1.00	0.86	**1.00**
FS45	86.01	13.99	79.77	20.23	28	4	**32**	0.88	0.83	**0.18**
FS47	80.97	19.03	69.04	30.96	7	0	**7**	1.00	0.75	**1.00**
FS48	87.25	12.75	82.60	17.40	46	0	**46**	1.00	0.85	**1.00**
FS49	50.05	49.95	43.33	56.67	5	1	**6**	0.83	0.47	**0.70**
FS50	80.98	19.02	77.77	22.23	93	16	**109**	0.85	0.79	**0.20**
FS51	94.23	5.77	93.48	6.52	53	5	**58**	0.91	0.94	**–0.18**
FS52	77.46	22.54	72.40	27.60	16	44	**60**	0.27	0.75	**–0.78**
FS54	84.09	15.91	74.39	25.61	57	0	**57**	1.00	0.79	**1.00**
FS55	96.44	3.56	96.61	3.39	42	0	**42**	1.00	0.97	**1.00**
FS56	87.88	12.12	88.13	11.87	104	0	**104**	1.00	0.88	**1.00**
FS59	82.52	17.48	80.21	19.79	4	0	**4**	1.00	0.81	**1.00**
FS60	80.73	19.27	78.62	21.38	32	0	**32**	1.00	0.80	**1.00**
FS62	93.89	6.11	94.03	5.97	32	0	**32**	1.00	0.94	**1.00**
FS65	79.08	20.92	70.36	29.64	4	0	**4**	1.00	0.75	**1.00**
FS66	91.34	8.66	82.98	17.02	6	0	**6**	1.00	0.87	**1.00**
FS67	92.87	7.13	85.43	14.57	36	18	**54**	0.67	0.89	**–0.61**
FS68	85.77	14.23	75.78	24.22	22	0	**22**	1.00	0.81	**1.00**
FS69	87.80	12.20	83.11	16.89	48	0	**48**	1.00	0.85	**1.00**
FS70	81.93	18.07	75.54	24.46	61	20	**81**	0.75	0.79	**–0.10**
FS71	85.56	14.44	78.05	21.95	0	5	**5**	0.00	0.82	**–1.00**
FS72	79.25	20.75	66.16	33.84	2	0	**2**	1.00	0.73	**1.00**
FS73	71.98	28.02	61.51	38.49	23	5	**28**	0.82	0.67	**0.39**
FS74	84.18	15.82	76.66	23.34	5	0	**5**	1.00	0.80	**1.00**
FS75	89.61	10.39	82.82	17.18	3	0	**3**	1.00	0.86	**1.00**
FS76	93.59	6.41	92.77	7.23	7	0	**7**	1.00	0.93	**1.00**
FS77	87.69	12.31	87.55	12.45	25	0	**25**	1.00	0.88	**1.00**
FS78	90.15	9.85	91.85	8.15	3	0	**3**	1.00	0.91	**1.00**
FS79	87.12	12.88	84.63	15.37	5	0	**5**	1.00	0.86	**1.00**
FS80	90.01	9.99	90.59	9.41	10	0	**10**	1.00	0.90	**1.00**
FS81	71.11	28.89	65.92	34.08	0	1	**1**	0.00	0.69	**–1.00**
FS82	96.15	3.85	97.14	2.86	5	3	**8**	0.63	0.97	**–0.89**
FS83	91.80	8.20	85.12	14.88	14	2	**16**	0.88	0.88	**–0.05**
FS84	89.35	10.65	91.57	8.43	16	5	**21**	0.76	0.90	**–0.50**
FS85	58.56	41.44	49.09	50.91	49	6	**55**	0.89	0.54	**0.75**
FS86	73.33	26.67	66.40	33.60	10	2	**12**	0.83	0.70	**0.37**
FS87	85.72	14.28	89.20	10.80	44	22	**66**	0.67	0.87	**–0.55**
FS88	95.07	4.93	85.52	14.48	61	0	**61**	1.00	0.90	**1.00**
FS90	93.07	6.93	93.87	6.13	3	0	**3**	1.00	0.93	**1.00**
FS91	73.02	26.98	67.62	32.38	49	0	**49**	1.00	0.70	**1.00**

FS92	83.97	16.03	75.42	24.58	19	4	**23**	0.83	0.80	**0.10**
FS93	99.48	0.52	98.96	1.04	62	0	**62**	1.00	0.99	**1.00**
FS94	93.10	6.90	94.21	5.79	21	4	**25**	0.84	0.94	**–0.48**
FS95	91.46	8.54	91.97	8.03	4	0	**4**	1.00	0.92	**1.00**
FS96	82.07	17.93	69.84	30.16	60	3	**63**	0.95	0.76	**0.73**
FS97	79.58	20.42	75.67	24.33	21	1	**22**	0.95	0.78	**0.72**
FS98	99.68	0.32	99.06	0.94	3	0	**3**	1.00	0.99	**1.00**
FS99	49.94	50.06	42.02	57.98	3	6	**9**	0.33	0.46	**–0.26**
FS100	99.12	0.88	98.06	1.94	18	0	**18**	1.00	0.99	**1.00**
FS101	89.84	10.16	90.27	9.73	22	8	**30**	0.73	0.90	**–0.53**
FS102	97.73	2.27	98.37	1.63	23	5	**28**	0.82	0.98	**–0.83**
FS103	69.42	30.58	60.69	39.31	0	1	**1**	0.00	0.65	**–1.00**
FS104	73.66	26.34	50.29	49.71	149	29	**178**	0.84	0.62	**0.52**
FS105	98.80	1.20	98.62	1.38	16	0	**16**	1.00	0.99	**1.00**
FS108	56.72	43.28	41.93	58.07	9	3	**12**	0.75	0.49	**0.51**
FS109	85.46	14.54	84.78	15.22	13	3	**16**	0.81	0.85	**–0.14**
FS110	91.87	8.13	83.29	16.71	51	7	**58**	0.88	0.88	**0.02**
FS111	90.13	9.87	81.11	18.89	33	3	**36**	0.92	0.86	**0.30**
FS112	79.75	20.25	71.81	28.19	98	7	**105**	0.93	0.76	**0.63**
FS113	84.43	15.57	74.60	25.40	89	30	**119**	0.75	0.80	**–0.13**
FS114	76.35	23.65	65.84	34.16	2	3	**5**	0.40	0.71	**–0.57**
FS116	62.86	37.14	54.66	45.34	15	3	**18**	0.83	0.59	**0.56**
FS117	94.56	5.44	96.59	3.41	14	0	**14**	1.00	0.96	**1.00**
FS118	99.80	0.20	99.00	1.00	35	0	**35**	1.00	0.99	**1.00**
FS119	69.45	30.55	66.03	33.97	4	1	**5**	0.80	0.68	**0.31**
FS120	67.81	32.19	55.21	44.79	23	2	**25**	0.92	0.62	**0.76**
FS122	47.83	52.17	40.44	59.56	4	6	**10**	0.40	0.44	**–0.08**
FS124	97.57	2.43	98.21	1.79	19	14	**33**	0.58	0.98	**–0.94**
Overall	**86.81**	**13.19**	**83.09**	**16.91**	**88.67**	**11.33**	**3291**	**0.89**	**0.85**	**0.16**

Southern Free State winter

	NLC2000 % land area		NLC2009 % land area		No. BKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EV01	91.35	8.65	97.92	2.08	8	0	**8**	1.00	0.95	**1.00**
FS01	90.69	9.31	91.18	8.82	5	2	**7**	0.71	0.91	**–0.60**
FS02	97.80	2.20	98.35	1.65	9	0	**9**	1.00	0.98	**1.00**
FS04	99.38	0.62	98.38	1.62	28	0	**28**	1.00	0.99	**1.00**
FS05	99.82	0.18	99.27	0.73	16	0	**16**	1.00	1.00	**1.00**
FS06	99.72	0.28	98.50	1.50	62	4	**66**	0.94	0.99	**–0.76**
FS07	97.95	2.05	97.20	2.80	42	23	**65**	0.65	0.98	**–0.91**
FS08	97.20	2.80	97.07	2.93	34	0	**34**	1.00	0.97	**1.00**
FS09	98.20	1.80	97.81	2.19	93	3	**96**	0.97	0.98	**–0.23**
FS10	94.30	5.70	95.95	4.05	24	0	**24**	1.00	0.95	**1.00**
FS11	96.98	3.02	97.94	2.06	95	0	**95**	1.00	0.97	**1.00**
FS12	96.33	3.67	96.12	3.88	383	25	**408**	0.94	0.96	**–0.25**
FS13	99.49	0.51	98.87	1.13	38	0	**38**	1.00	0.99	**1.00**
FS14	99.92	0.08	98.90	1.10	11	0	**11**	1.00	0.99	**1.00**
FS15	99.09	0.91	99.36	0.64	9	1	**10**	0.90	0.99	**–0.87**
FS16	92.52	7.48	90.86	9.14	18	0	**18**	1.00	0.92	**1.00**
FS17	94.90	5.10	94.57	5.43	174	3	**177**	0.98	0.95	**0.53**
FS18	95.76	4.24	95.73	4.27	66	0	**66**	1.00	0.96	**1.00**
FS19	82.64	17.36	74.03	25.97	41	2	**43**	0.95	0.78	**0.70**
FS20	81.12	18.88	73.08	26.92	16	0	**16**	1.00	0.77	**1.00**
FS22	84.81	15.19	85.32	14.68	9	0	**9**	1.00	0.85	**1.00**
FS23	94.58	5.42	94.45	5.55	21	0	**21**	1.00	0.95	**1.00**
FS24	96.18	3.82	97.18	2.82	5	10	**15**	0.33	0.97	**–0.97**
FS25	96.69	3.31	97.70	2.30	59	9	**68**	0.87	0.97	**–0.68**
FS26	94.80	5.20	95.17	4.83	19	7	**26**	0.73	0.95	**–0.75**
FS27	97.10	2.90	97.66	2.34	89	33	**122**	0.73	0.97	**–0.86**
FS28	97.24	2.76	92.07	7.93	15	0	**15**	1.00	0.95	**1.00**

FS29	98.34	1.66	96.27	3.73	70	3	73	0.96	0.97	–0.21
FS30	78.52	21.48	72.16	27.84	61	0	61	1.00	0.75	1.00
FS31	91.10	8.90	89.07	10.93	97	74	171	0.57	0.90	–0.75
FS32	94.46	5.54	94.92	5.08	4	0	4	1.00	0.95	1.00
FS33	94.31	5.69	95.75	4.25	3	0	3	1.00	0.95	1.00
FS35	82.89	17.11	73.74	26.26	87	14	101	0.86	0.78	0.26
FS39	66.18	33.82	65.86	34.14	1	0	1	1.00	0.66	1.00
FS40	93.52	6.48	92.64	7.36	6	0	6	1.00	0.93	1.00
FS42	77.79	22.21	87.50	12.50	8	3	11	0.73	0.83	–0.28
FS44	90.63	9.37	81.27	18.73	10	5	15	0.67	0.86	–0.51
FS45	86.01	13.99	79.77	20.23	45	12	57	0.79	0.83	–0.13
FS47	80.97	19.03	69.04	30.96	11	3	14	0.79	0.75	0.10
FS48	87.25	12.75	82.60	17.40	22	2	24	0.92	0.85	0.32
FS49	50.05	49.95	43.33	56.67	0	3	3	0.00	0.47	–1.00
FS50	80.98	19.02	77.77	22.23	81	46	127	0.64	0.79	–0.37
FS51	94.23	5.77	93.48	6.52	121	18	139	0.87	0.94	–0.39
FS52	77.46	22.54	72.40	27.60	57	81	138	0.41	0.75	–0.62
FS53	65.51	34.49	54.64	45.36	0	5	5	0.00	0.60	–1.00
FS54	84.09	15.91	74.39	25.61	94	4	98	0.96	0.79	0.72
FS55	96.44	3.56	96.61	3.39	37	0	37	1.00	0.97	1.00
FS56	87.88	12.12	88.13	11.87	175	0	175	1.00	0.88	1.00
FS57	88.76	11.24	79.49	20.51	5	0	5	1.00	0.84	1.00
FS59	82.52	17.48	80.21	19.79	12	0	12	1.00	0.81	1.00
FS60	80.73	19.27	78.62	21.38	14	0	14	1.00	0.80	1.00
FS61	72.67	27.33	51.81	48.19	7	31	38	0.18	0.62	–0.76
FS62	93.89	6.11	94.03	5.97	33	9	42	0.79	0.94	–0.62
FS63	92.72	7.28	83.40	16.60	5	5	10	0.50	0.88	–0.76
FS65	79.08	20.92	70.36	29.64	6	0	6	1.00	0.75	1.00
FS66	91.34	8.66	82.98	17.02	10	2	12	0.83	0.87	–0.15
FS67	92.87	7.13	85.43	14.57	32	30	62	0.52	0.89	–0.77
FS68	85.77	14.23	75.78	24.22	11	0	11	1.00	0.81	1.00
FS69	87.80	12.20	83.11	16.89	159	27	186	0.85	0.85	0.00
FS70	81.93	18.07	75.54	24.46	83	57	140	0.59	0.79	–0.44
FS71	85.56	14.44	78.05	21.95	3	10	13	0.23	0.82	–0.87
FS72	79.25	20.75	66.16	33.84	6	4	10	0.60	0.73	–0.28
FS73	71.98	28.02	61.51	38.49	51	3	54	0.94	0.67	0.79
FS74	84.18	15.82	76.66	23.34	5	0	5	1.00	0.80	1.00
FS76	93.59	6.41	92.77	7.23	8	0	8	1.00	0.93	1.00
FS77	87.69	12.31	87.55	12.45	45	13	58	0.78	0.88	–0.34
FS79	87.12	12.88	84.63	15.37	6	0	6	1.00	0.86	1.00
FS80	90.01	9.99	90.59	9.41	44	0	44	1.00	0.90	1.00
FS81	71.11	28.89	65.92	34.08	7	7	14	0.50	0.69	–0.37
FS82	96.15	3.85	97.14	2.86	9	0	9	1.00	0.97	1.00
FS83	91.80	8.20	85.12	14.88	5	0	5	1.00	0.88	1.00
FS84	89.35	10.65	91.57	8.43	37	0	37	1.00	0.90	1.00
FS85	58.56	41.44	49.09	50.91	51	46	97	0.53	0.54	–0.02
FS86	73.33	26.67	66.40	33.60	4	8	12	0.33	0.70	–0.65
FS87	85.72	14.28	89.20	10.80	95	29	124	0.77	0.87	–0.36
FS88	95.07	4.93	85.52	14.48	73	6	79	0.92	0.90	0.13
FS90	93.07	6.93	93.87	6.13	25	0	25	1.00	0.93	1.00
FS91	73.02	26.98	67.62	32.38	38	1	39	0.97	0.70	0.88
FS92	83.97	16.03	75.42	24.58	32	12	44	0.73	0.80	–0.19
FS93	99.48	0.52	98.96	1.04	104	0	104	1.00	0.99	1.00
FS94	93.10	6.90	94.21	5.79	10	4	14	0.71	0.94	–0.71
FS95	91.46	8.54	91.97	8.03	17	0	17	1.00	0.92	1.00
FS96	82.07	17.93	69.84	30.16	3	4	7	0.43	0.76	–0.62
FS97	79.58	20.42	75.67	24.33	29	2	31	0.94	0.78	0.61
FS99	49.94	50.06	42.02	57.98	0	2	2	0.00	0.46	–1.00
FS100	99.12	0.88	98.06	1.94	12	0	12	1.00	0.99	1.00
FS101	89.84	10.16	90.27	9.73	7	8	15	0.47	0.90	–0.82
FS102	97.73	2.27	98.37	1.63	23	8	31	0.74	0.98	–0.89
FS103	69.42	30.58	60.69	39.31	4	0	4	1.00	0.65	1.00

FS104	73.66	26.34	50.29	49.71	122	62	**184**	0.66	0.62	**0.09**
FS105	98.80	1.20	98.62	1.38	15	0	**15**	1.00	0.99	**1.00**
FS106	60.48	39.52	44.84	55.16	2	0	**2**	1.00	0.53	**1.00**
FS108	56.72	43.28	41.93	58.07	23	11	**34**	0.68	0.49	**0.36**
FS109	85.46	14.54	84.78	15.22	74	39	**113**	0.65	0.85	**–0.50**
FS110	91.87	8.13	83.29	16.71	100	12	**112**	0.89	0.88	**0.08**
FS111	90.13	9.87	81.11	18.89	18	16	**34**	0.53	0.86	**–0.68**
FS112	79.75	20.25	71.81	28.19	107	9	**116**	0.92	0.76	**0.58**
FS113	84.43	15.57	74.60	25.40	111	99	**210**	0.53	0.80	**–0.55**
FS114	76.35	23.65	65.84	34.16	13	0	**13**	1.00	0.71	**1.00**
FS116	62.86	37.14	54.66	45.34	29	4	**33**	0.88	0.59	**0.67**
FS117	94.56	5.44	96.59	3.41	31	0	**31**	1.00	0.96	**1.00**
FS118	99.80	0.20	99.00	1.00	56	3	**59**	0.95	0.99	**–0.80**
FS119	69.45	30.55	66.03	33.97	11	7	**18**	0.61	0.68	**–0.14**
FS120	67.81	32.19	55.21	44.79	44	10	**54**	0.81	0.62	**0.47**
FS121	83.91	16.09	70.44	29.56	2	0	**2**	1.00	0.77	**1.00**
FS122	47.83	52.17	40.44	59.56	9	2	**11**	0.82	0.44	**0.70**
FS124	97.57	2.43	98.21	1.79	4	2	**6**	0.67	0.98	**–0.92**
FS126	85.15	14.85	81.23	18.77	3	0	**3**	1.00	0.83	**1.00**
Overall	**86.11**	**13.89**	**81.91**	**18.09**	**81.09**	**18.91**	**5282**	**0.81**	**0.84**	**–0.10**

Wakkerstroom summer

	NLC2000 % land area		**NLC2009 % land area**		**No. BKs**			**Jacobs index**		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
MW02	76.39	23.61	75.11	24.89	3	0	**3**	1.00	0.76	**1.00**
MW03	92.26	7.74	87.61	12.39	39	1	**40**	0.98	0.90	**0.63**
MW04	92.33	7.67	88.40	11.60	9	0	**9**	1.00	0.90	**1.00**
MW05	89.06	10.94	78.91	21.09	7	0	**7**	1.00	0.84	**1.00**
MW06	83.89	16.11	68.40	31.60	18	2	**20**	0.90	0.76	**0.48**
MW07	87.13	12.87	78.43	21.57	25	4	**29**	0.86	0.83	**0.13**
MW08	81.43	18.57	80.97	19.03	1	0	**1**	1.00	0.81	**1.00**
MW09	87.36	12.64	84.41	15.59	3	0	**3**	1.00	0.86	**1.00**
MW10	92.08	7.92	83.78	16.22	12	0	**12**	1.00	0.88	**1.00**
Overall	**86.68**	**13.32**	**80.93**	**19.07**	**94.35**	**5.65**	**124**	**0.94**	**0.84**	**0.53**

Wakkerstroom winter

	NLC2000 % land area		**NLC2009 % land area**		**No. BKs**			**Jacobs index**		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
MW02	76.39	23.61	75.11	24.89	0	2	**2**	0.00	0.76	**–1.00**
MW03	92.26	7.74	87.61	12.39	27	16	**43**	0.63	0.90	**–0.68**
MW04	92.33	7.67	88.40	11.60	13	0	**13**	1.00	0.90	**1.00**
MW05	89.06	10.94	78.91	21.09	13	11	**24**	0.54	0.84	**–0.63**
MW06	83.89	16.11	68.40	31.60	9	16	**25**	0.36	0.76	**–0.70**
MW07	87.13	12.87	78.43	21.57	26	64	**90**	0.29	0.83	**–0.84**
MW09	87.36	12.64	84.41	15.59	8	0	**8**	1.00	0.86	**1.00**
MW10	92.08	7.92	83.78	16.22	2	0	**2**	1.00	0.88	**1.00**
Overall	**87.55**	**12.45**	**80.92**	**19.08**	**47.34**	**52.66**	**207**	**0.47**	**0.84**	**–0.71**

(b)

Eastern Cape Karoo + Beaufort West summer

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EM01	95.20	4.80	97.94	2.06	4	0	**4**	1.00	0.97	**1.00**
EM02	92.54	7.46	97.85	2.15	0	1	**1**	0.00	0.95	**–1.00**
EP01	84.90	15.10	97.93	2.07	98	0	**98**	1.00	0.91	**1.00**
EP02	98.39	1.61	98.56	1.44	13	0	**13**	1.00	0.98	**1.00**
EP03	90.30	9.70	96.94	3.06	24	0	**24**	1.00	0.94	**1.00**
EP04	90.40	9.60	97.92	2.08	47	0	**47**	1.00	0.94	**1.00**
EP06	70.40	29.60	82.60	17.40	7	0	**7**	1.00	0.77	**1.00**
EP08	99.10	0.90	98.62	1.38	77	3	**80**	0.96	0.99	**–0.54**
EP10	76.55	23.45	96.47	3.53	35	5	**40**	0.88	0.87	**0.04**
ES01	99.08	0.92	98.56	1.44	1	0	**1**	1.00	0.99	**1.00**
ES02	77.87	22.13	81.70	18.30	14	0	**14**	1.00	0.80	**1.00**
ES03	96.82	3.18	95.30	4.70	64	11	**75**	0.85	0.96	**–0.61**
ES04	97.38	2.62	97.41	2.59	2	0	**2**	1.00	0.97	**1.00**
ES05	94.08	5.92	90.37	9.63	1	0	**1**	1.00	0.92	**1.00**
ES08	92.13	7.87	97.68	2.32	10	0	**10**	1.00	0.95	**1.00**
ES10	98.84	1.16	98.90	1.10	3	0	**3**	1.00	0.99	**1.00**
WB01	99.77	0.23	99.79	0.21	294	0	**294**	1.00	1.00	**1.00**
WB03	91.23	8.77	98.90	1.10	39	0	**39**	1.00	0.95	**1.00**
Overall	**91.88**	**8.12**	**95.90**	**4.10**	**97.34**	**2.66**	**753**	**0.97**	**0.94**	**0.41**

Eastern Cape Karoo + Beaufort West winter

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EM02	92.54	7.46	97.85	2.15	1	0	**1**	1.00	0.95	**1.00**
EP01	84.90	15.10	97.93	2.07	179	0	**179**	1.00	0.91	**1.00**
EP02	98.39	1.61	98.56	1.44	29	0	**29**	1.00	0.98	**1.00**
EP03	90.30	9.70	96.94	3.06	9	0	**9**	1.00	0.94	**1.00**
EP04	90.40	9.60	97.92	2.08	119	0	**119**	1.00	0.94	**1.00**
EP06	70.40	29.60	82.60	17.40	6	5	**11**	0.55	0.77	**–0.46**
EP07	92.19	7.81	97.38	2.62	4	0	**4**	1.00	0.95	**1.00**
EP08	99.10	0.90	98.62	1.38	195	15	**210**	0.93	0.99	**–0.74**
EP10	76.55	23.45	96.47	3.53	61	7	**68**	0.90	0.87	**0.15**
ES01	99.08	0.92	98.56	1.44	14	0	**14**	1.00	0.99	**1.00**
ES02	77.87	22.13	81.70	18.30	28	0	**28**	1.00	0.80	**1.00**
ES03	96.82	3.18	95.30	4.70	104	0	**104**	1.00	0.96	**1.00**
ES04	97.38	2.62	97.41	2.59	3	3	**6**	0.50	0.97	**–0.95**
ES06	98.83	1.17	96.03	3.97	2	0	**2**	1.00	0.97	**1.00**
ES08	92.13	7.87	97.68	2.32	21	0	**21**	1.00	0.95	**1.00**
ES10	98.84	1.16	98.90	1.10	3	0	**3**	1.00	0.99	**1.00**
WB01	99.77	0.23	99.79	0.21	325	0	**325**	1.00	1.00	**1.00**
WB03	91.23	8.77	98.90	1.10	94	0	**94**	1.00	0.95	**1.00**
Overall	**92.09**	**7.91**	**96.30**	**3.70**	**97.56**	**2.44**	**1227**	**0.98**	**0.94**	**0.42**

Eastern Karoo summer

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK011	98.39	1.61	99.26	0.74	100.00	0.00	8	0	8	1.00	0.99	1.00
NK012	99.20	0.80	98.48	1.52	99.85	0.15	1	0	1	1.00	0.99	1.00
NK013	99.06	0.94	99.19	0.81	100.00	0.00	1	0	1	1.00	0.99	1.00
NK021	100.00	0.00	97.79	2.21	99.96	0.04	11	0	11	1.00	0.99	1.00
NK022	97.74	2.26	90.81	9.19	100.00	0.00	16	0	16	1.00	0.96	1.00
NK023	97.50	2.50	91.01	8.99	100.00	0.00	40	0	40	1.00	0.96	1.00
NK031	99.07	0.93	97.54	2.46	100.00	0.00	12	0	12	1.00	0.99	1.00
NK032	98.52	1.48	98.40	1.60	100.00	0.00	13	0	13	1.00	0.99	1.00
NK033	100.00	0.00	99.91	0.09	100.00	0.00	4	0	4	1.00	1.00	1.00
NK041	97.97	2.03	98.71	1.29	100.00	0.00	16	0	16	1.00	0.99	1.00
NK042	100.00	0.00	97.91	2.09	100.00	0.00	10	0	10	1.00	0.99	1.00
NK043	100.00	0.00	99.64	0.36	100.00	0.00	2	0	2	1.00	1.00	1.00
NK044	100.00	0.00	99.83	0.17	100.00	0.00	3	0	3	1.00	1.00	1.00
NK061	100.00	0.00	99.96	0.04	100.00	0.00	11	0	11	1.00	1.00	1.00
NK062	99.54	0.46	100.00	0.00	100.00	0.00	6	0	6	1.00	1.00	1.00
NK063	100.00	0.00	99.84	0.16	100.00	0.00	7	0	7	1.00	1.00	1.00
NK071	100.00	0.00	95.84	4.16	100.00	0.00	6	0	6	1.00	0.99	1.00
NK091	99.88	0.12	91.90	8.10	100.00	0.00	17	0	17	1.00	0.97	1.00
NK092	100.00	0.00	95.52	4.48	100.00	0.00	3	0	3	1.00	0.99	1.00
NK093	100.00	0.00	87.74	12.26	100.00	0.00	4	0	4	1.00	0.96	1.00
NK101	96.64	3.36	97.76	2.24	97.91	2.09	5	8	13	0.38	0.97	–0.97
NK102	99.04	0.96	99.70	0.30	99.69	0.31	8	0	8	1.00	0.99	1.00
NK112	99.85	0.15	99.00	1.00	100.00	0.00	2	0	2	1.00	1.00	1.00
NK113	99.73	0.27	99.04	0.96	100.00	0.00	2	0	2	1.00	1.00	1.00
NK142	99.67	0.33	99.33	0.67	99.74	0.26	8	0	8	1.00	1.00	1.00
NK151	99.80	0.20	99.94	0.06	100.00	0.00	1	0	1	1.00	1.00	1.00
NK171	100.00	0.00	99.93	0.07	100.00	0.00	2	0	2	1.00	1.00	1.00
NK172	100.00	0.00	99.65	0.35	99.89	0.11	2	0	2	1.00	1.00	1.00
NK181	100.00	0.00	98.19	1.81	98.70	1.30	2	0	2	1.00	0.99	1.00
NK182	99.17	0.83	94.73	5.27	96.73	3.27	5	0	5	1.00	0.97	1.00
NK192	98.05	1.95	98.65	1.35	98.57	1.43	1	0	1	1.00	0.98	1.00
NK202	99.95	0.05	99.67	0.33	100.00	0.00	3	0	3	1.00	1.00	1.00
NK211	100.00	0.00	92.28	7.72	100.00	0.00	16	0	16	1.00	0.97	1.00
NK212	100.00	0.00	95.54	4.46	100.00	0.00	3	0	3	1.00	0.99	1.00
NK213	100.00	0.00	96.84	3.16	100.00	0.00	4	0	4	1.00	0.99	1.00
NK221	97.87	2.13	95.90	4.10	100.00	0.00	20	0	20	1.00	0.98	1.00
NK222	100.00	0.00	98.93	1.07	99.96	0.04	2	0	2	1.00	1.00	1.00
NK231	99.46	0.54	99.03	0.97	100.00	0.00	24	2	26	0.92	0.99	–0.89
NK232	99.91	0.09	96.42	3.58	100.00	0.00	2	0	2	1.00	0.99	1.00
NK311	99.26	0.74	99.04	0.96	100.00	0.00	5	0	5	1.00	0.99	1.00
NK313	98.83	1.17	99.95	0.05	100.00	0.00	3	0	3	1.00	1.00	1.00
NK321	93.10	6.90	92.39	7.61	99.94	0.06	12	0	12	1.00	0.95	1.00
NK322	99.97	0.03	97.33	2.67	100.00	0.00	10	0	10	1.00	0.99	1.00
NK323	95.85	4.15	96.11	3.89	99.97	0.03	11	0	11	1.00	0.97	1.00
NK331	100.00	0.00	97.41	2.59	98.95	1.05	10	0	10	1.00	0.99	1.00
NK333	100.00	0.00	99.82	0.18	100.00	0.00	1	0	1	1.00	1.00	1.00
NK341	99.56	0.44	99.29	0.71	99.31	0.69	3	0	3	1.00	0.99	1.00
NK351	97.74	2.26	99.82	0.18	99.97	0.03	4	0	4	1.00	0.99	1.00
NK352	99.10	0.90	100.00	0.00	100.00	0.00	8	0	8	1.00	1.00	1.00
NK353	100.00	0.00	99.96	0.04	100.00	0.00	4	0	4	1.00	1.00	1.00
NK361	100.00	0.00	97.27	2.73	100.00	0.00	22	0	22	1.00	0.99	1.00
NK363	100.00	0.00	99.39	0.61	100.00	0.00	11	0	11	1.00	1.00	1.00
NK371	99.28	0.72	98.82	1.18	99.24	0.76	6	0	6	1.00	0.99	1.00
NK373	100.00	0.00	99.80	0.20	100.00	0.00	2	0	2	1.00	1.00	1.00
NK391	91.72	8.28	83.63	16.37	99.93	0.07	39	0	39	1.00	0.92	1.00
NK392	100.00	0.00	87.45	12.55	96.61	3.39	2	0	2	1.00	0.95	1.00
NK393	100.00	0.00	99.00	1.00	100.00	0.00	3	0	3	1.00	1.00	1.00
NK442	95.54	4.46	86.44	13.56	100.00	0.00	2	0	2	1.00	0.94	1.00

NK443	94.20	5.80	72.40	27.60	98.63	1.37	2	0	**2**	1.00	0.88	**1.00**
NK451	94.11	5.89	86.08	13.92	99.98	0.02	6	0	**6**	1.00	0.93	**1.00**
NK452	99.39	0.61	99.00	1.00	99.63	0.37	2	0	**2**	1.00	0.99	**1.00**
NK453	98.03	1.97	94.48	5.52	100.00	0.00	2	0	**2**	1.00	0.98	**1.00**
Overall	**98.94**	**1.06**	**96.62**	**3.38**	**99.72**	**0.28**	**97.93**	**2.07**	**483**	**0.98**	**0.98**	**–0.14**

Eastern Karoo winter

	NLC1994 % land area		NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK011	98.39	1.61	99.26	0.74	100.00	0.00	4	0	**4**	1.00	0.99	**1.00**
NK012	99.20	0.80	98.48	1.52	99.85	0.15	6	0	**6**	1.00	0.99	**1.00**
NK021	100.00	0.00	97.79	2.21	99.96	0.04	21	0	**21**	1.00	0.99	**1.00**
NK022	97.74	2.26	90.81	9.19	100.00	0.00	26	0	**26**	1.00	0.96	**1.00**
NK023	97.50	2.50	91.01	8.99	100.00	0.00	36	0	**36**	1.00	0.96	**1.00**
NK031	99.07	0.93	97.54	2.46	100.00	0.00	9	0	**9**	1.00	0.99	**1.00**
NK032	98.52	1.48	98.40	1.60	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK033	100.00	0.00	99.91	0.09	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK041	97.97	2.03	98.71	1.29	100.00	0.00	7	0	**7**	1.00	0.99	**1.00**
NK042	100.00	0.00	97.91	2.09	100.00	0.00	1	0	**1**	1.00	0.99	**1.00**
NK043	100.00	0.00	99.64	0.36	100.00	0.00	12	0	**12**	1.00	1.00	**1.00**
NK044	100.00	0.00	99.83	0.17	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK061	100.00	0.00	99.96	0.04	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK062	99.54	0.46	100.00	0.00	100.00	0.00	5	3	**8**	0.63	1.00	**–0.99**
NK063	100.00	0.00	99.84	0.16	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK071	100.00	0.00	95.84	4.16	100.00	0.00	1	0	**1**	1.00	0.99	**1.00**
NK073	100.00	0.00	99.38	0.62	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK081	100.00	0.00	99.66	0.34	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK091	99.88	0.12	91.90	8.10	100.00	0.00	26	0	**26**	1.00	0.97	**1.00**
NK092	100.00	0.00	95.52	4.48	100.00	0.00	9	0	**9**	1.00	0.99	**1.00**
NK101	96.64	3.36	97.76	2.24	97.91	2.09	5	2	**7**	0.71	0.97	**–0.88**
NK102	99.04	0.96	99.70	0.30	99.69	0.31	1	0	**1**	1.00	0.99	**1.00**
NK111	98.18	1.82	97.08	2.92	100.00	0.00	1	1	**2**	0.50	0.98	**–0.97**
NK112	99.85	0.15	99.00	1.00	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK113	99.73	0.27	99.04	0.96	100.00	0.00	1	0	**1**	1.00	1.00	**1.00**
NK131	95.44	4.56	95.14	4.86	95.31	4.69	2	0	**2**	1.00	0.95	**1.00**
NK142	99.67	0.33	99.33	0.67	99.74	0.26	10	0	**10**	1.00	1.00	**1.00**
NK151	99.80	0.20	99.94	0.06	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK171	100.00	0.00	99.93	0.07	100.00	0.00	3	1	**4**	0.75	1.00	**–1.00**
NK181	100.00	0.00	98.19	1.81	98.70	1.30	8	0	**8**	1.00	0.99	**1.00**
NK182	99.17	0.83	94.73	5.27	96.73	3.27	2	0	**2**	1.00	0.97	**1.00**
NK183	99.77	0.23	96.15	3.85	96.71	3.29	4	0	**4**	1.00	0.98	**1.00**
NK192	98.05	1.95	98.65	1.35	98.57	1.43	1	0	**1**	1.00	0.98	**1.00**
NK193	95.38	4.62	93.29	6.71	93.13	6.87	2	0	**2**	1.00	0.94	**1.00**
NK202	99.95	0.05	99.67	0.33	100.00	0.00	15	0	**15**	1.00	1.00	**1.00**
NK211	100.00	0.00	92.28	7.72	100.00	0.00	5	3	**8**	0.63	0.97	**–0.92**
NK212	100.00	0.00	95.54	4.46	100.00	0.00	9	0	**9**	1.00	0.99	**1.00**
NK213	100.00	0.00	96.84	3.16	100.00	0.00	10	0	**10**	1.00	0.99	**1.00**
NK221	97.87	2.13	95.90	4.10	100.00	0.00	29	0	**29**	1.00	0.98	**1.00**
NK222	100.00	0.00	98.93	1.07	99.96	0.04	7	0	**7**	1.00	1.00	**1.00**
NK231	99.46	0.54	99.03	0.97	100.00	0.00	20	0	**20**	1.00	0.99	**1.00**
NK232	99.91	0.09	96.42	3.58	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK233	100.00	0.00	98.59	1.41	100.00	0.00	1	0	**1**	1.00	1.00	**1.00**
NK263	87.72	12.28	91.43	8.57	92.74	7.26	3	0	**3**	1.00	0.91	**1.00**
NK281	98.33	1.67	71.85	28.15	95.87	4.13	8	0	**8**	1.00	0.89	**1.00**
NK282	91.19	8.81	77.96	22.04	93.73	6.27	2	0	**2**	1.00	0.88	**1.00**
NK311	99.26	0.74	99.04	0.96	100.00	0.00	14	0	**14**	1.00	0.99	**1.00**
NK312	100.00	0.00	97.95	2.05	99.94	0.06	4	0	**4**	1.00	0.99	**1.00**
NK313	98.83	1.17	99.95	0.05	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK321	93.10	6.90	92.39	7.61	99.94	0.06	34	0	**34**	1.00	0.95	**1.00**

NK322	99.97	0.03	97.33	2.67	100.00	0.00	13	0	**13**	1.00	0.99	**1.00**
NK323	95.85	4.15	96.11	3.89	99.97	0.03	22	0	**22**	1.00	0.97	**1.00**
NK341	99.56	0.44	99.29	0.71	99.31	0.69	11	0	**11**	1.00	0.99	**1.00**
NK342	97.74	2.26	98.39	1.61	98.29	1.71	9	0	**9**	1.00	0.98	**1.00**
NK351	97.74	2.26	99.82	0.18	99.97	0.03	2	0	**2**	1.00	0.99	**1.00**
NK352	99.10	0.90	100.00	0.00	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK353	100.00	0.00	99.96	0.04	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK361	100.00	0.00	97.27	2.73	100.00	0.00	23	0	**23**	1.00	0.99	**1.00**
NK363	100.00	0.00	99.39	0.61	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK372	100.00	0.00	99.79	0.21	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK373	100.00	0.00	99.80	0.20	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK391	91.72	8.28	83.63	16.37	99.93	0.07	37	0	**37**	1.00	0.92	**1.00**
NK392	100.00	0.00	87.45	12.55	96.61	3.39	8	0	**8**	1.00	0.95	**1.00**
NK393	100.00	0.00	99.00	1.00	100.00	0.00	1	0	**1**	1.00	1.00	**1.00**
NK451	94.11	5.89	86.08	13.92	99.98	0.02	26	0	**26**	1.00	0.93	**1.00**
Overall	**98.62**	**1.38**	**96.41**	**3.59**	**99.25**	**0.75**	**98.29**	**1.71**	**586**	**0.98**	**0.98**	**0.06**

Little Karoo summer

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
WK03	65.28	34.72	55.80	44.20	0	1	**1**	0.00	0.61	**–1.00**
WU01	96.37	3.63	91.63	8.37	4	4	**8**	0.50	0.94	**–0.88**
WU02	94.83	5.17	76.05	23.95	0	1	**1**	0.00	0.85	**–1.00**
WU03	82.56	17.44	83.39	16.61	2	0	**2**	1.00	0.83	**1.00**
WU05	47.45	52.55	29.44	70.56	0	1	**1**	0.00	0.38	**–1.00**
Overall	**76.06**	**23.94**	**65.29**	**34.71**	**46.15**	**53.85**	**13**	**0.46**	**0.71**	**–0.48**

Little Karoo winter

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
WK01	67.82	32.18	61.33	38.67	1	0	**1**	1.00	0.65	**1.00**
WK03	65.28	34.72	55.80	44.20	2	0	**2**	1.00	0.61	**1.00**
WU01	96.37	3.63	91.63	8.37	9	0	**9**	1.00	0.94	**1.00**
WU02	94.83	5.17	76.05	23.95	1	0	**1**	1.00	0.85	**1.00**
WU03	82.56	17.44	83.39	16.61	8	4	**12**	0.67	0.83	**–0.42**
WU07	90.71	9.29	81.72	18.28	12	0	**12**	1.00	0.86	**1.00**
Overall	**84.69**	**15.31**	**76.56**	**23.44**	**89.19**	**10.81**	**37**	**0.89**	**0.81**	**0.33**

Overberg summer

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
OV05	18.87	81.13	4.18	95.82	8	83	**91**	0.09	0.12	**–0.15**
OV06	19.49	80.51	6.06	93.94	2	20	**22**	0.09	0.13	**–0.19**
OV07	15.25	84.75	3.16	96.84	0	4	**4**	0.00	0.09	**–1.00**
OV08	10.58	89.42	3.26	96.74	1	2	**3**	0.33	0.07	**0.74**
OV09	12.43	87.57	2.28	97.72	0	1	**1**	0.00	0.07	**–1.00**
OV10	7.72	92.28	1.70	98.30	0	8	**8**	0.00	0.05	**–1.00**
OV11	47.72	52.28	34.99	65.01	2	0	**2**	1.00	0.41	**1.00**
OV12	28.68	71.32	20.52	79.48	0	1	**1**	0.00	0.25	**–1.00**
OV13	19.68	80.32	3.96	96.04	7	48	**55**	0.13	0.12	**0.04**
OV14	21.62	78.38	6.43	93.57	8	25	**33**	0.24	0.14	**0.32**
OV16	9.72	90.28	3.42	96.58	0	47	**47**	0.00	0.07	**–1.00**
OV19	15.54	84.46	3.20	96.80	0	29	**29**	0.00	0.09	**–1.00**
OV20	11.69	88.31	1.50	98.50	0	5	**5**	0.00	0.07	**–1.00**
OV21	14.74	85.26	2.75	97.25	0	1	**1**	0.00	0.09	**–1.00**
Overall	**18.17**	**81.83**	**6.82**	**93.18**	**9.27**	**90.73**	**302**	**0.09**	**0.12**	**–0.17**

Overberg winter

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
OV05	18.87	81.13	4.18	95.82	12	151	**163**	0.07	0.12	**–0.24**
OV06	19.49	80.51	6.06	93.94	9	67	**76**	0.12	0.13	**–0.04**
OV07	15.25	84.75	3.16	96.84	5	42	**47**	0.11	0.09	**0.08**
OV08	10.58	89.42	3.26	96.74	0	16	**16**	0.00	0.07	**–1.00**
OV10	7.72	92.28	1.70	98.30	0	8	**8**	0.00	0.05	**–1.00**
OV12	28.68	71.32	20.52	79.48	0	4	**4**	0.00	0.25	**–1.00**
OV13	19.68	80.32	3.96	96.04	28	121	**149**	0.19	0.12	**0.27**
OV14	21.62	78.38	6.43	93.57	15	46	**61**	0.25	0.14	**0.33**
OV15	14.33	85.67	3.76	96.24	8	12	**20**	0.40	0.09	**0.74**
OV16	9.72	90.28	3.42	96.58	4	70	**74**	0.05	0.07	**–0.10**
OV19	15.54	84.46	3.20	96.80	0	45	**45**	0.00	0.09	**–1.00**
OV20	11.69	88.31	1.50	98.50	3	7	**10**	0.30	0.07	**0.72**
OV27	42.27	57.73	26.81	73.19	2	0	**2**	1.00	0.35	**1.00**
OV32	4.99	95.01	0.09	99.91	0	1	**1**	0.00	0.03	**–1.00**
Overall	**17.68**	**82.32**	**6.48**	**93.52**	**12.72**	**87.28**	**676**	**0.13**	**0.12**	**0.03**

Southern Free State summer

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
FS06	99.72	0.28	98.50	1.50	1	0	**1**	1.00	0.99	**1.00**
FS07	97.95	2.05	97.20	2.80	2	0	**2**	1.00	0.98	**1.00**
FS19	82.64	17.36	74.03	25.97	1	0	**1**	1.00	0.78	**1.00**
FS27	97.10	2.90	97.66	2.34	6	0	**6**	1.00	0.97	**1.00**
FS32	94.46	5.54	94.92	5.08	3	0	**3**	1.00	0.95	**1.00**
FS50	80.98	19.02	77.77	22.23	2	5	**7**	0.29	0.79	**–0.81**
FS55	96.44	3.56	96.61	3.39	2	0	**2**	1.00	0.97	**1.00**
FS60	80.73	19.27	78.62	21.38	6	0	**6**	1.00	0.80	**1.00**
FS62	93.89	6.11	94.03	5.97	1	0	**1**	1.00	0.94	**1.00**
FS73	71.98	28.02	61.51	38.49	9	0	**9**	1.00	0.67	**1.00**
FS77	87.69	12.31	87.55	12.45	1	0	**1**	1.00	0.88	**1.00**
FS87	85.72	14.28	89.20	10.80	6	3	**9**	0.67	0.87	**–0.55**
FS118	99.80	0.20	99.00	1.00	1	0	**1**	1.00	0.99	**1.00**
Overall	**89.79**	**10.21**	**87.85**	**12.15**	**83.67**	**16.33**	**49**	**0.84**	**0.89**	**–0.22**

Southern Free State winter

	NLC2000 % land area		NLC2009 % land area		No. KKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
FS05	99.82	0.18	99.27	0.73	1	0	**1**	1.00	1.00	**1.00**
FS09	98.20	1.80	97.81	2.19	2	0	**2**	1.00	0.98	**1.00**
FS13	99.49	0.51	98.87	1.13	4	0	**4**	1.00	0.99	**1.00**
FS27	97.10	2.90	97.66	2.34	4	0	**4**	1.00	0.97	**1.00**
FS32	94.46	5.54	94.92	5.08	3	0	**3**	1.00	0.95	**1.00**
FS38	74.42	25.58	58.49	41.51	5	0	**5**	1.00	0.66	**1.00**
FS42	77.79	22.21	87.50	12.50	2	0	**2**	1.00	0.83	**1.00**
FS58	87.24	12.76	84.70	15.30	2	0	**2**	1.00	0.86	**1.00**
FS59	82.52	17.48	80.21	19.79	4	0	**4**	1.00	0.81	**1.00**
FS60	80.73	19.27	78.62	21.38	1	0	**1**	1.00	0.80	**1.00**
FS61	72.67	27.33	51.81	48.19	2	0	**2**	1.00	0.62	**1.00**
FS77	87.69	12.31	87.55	12.45	12	0	**12**	1.00	0.88	**1.00**
FS87	85.72	14.28	89.20	10.80	4	0	**4**	1.00	0.87	**1.00**
FS104	73.66	26.34	50.29	49.71	0	1	**1**	0.00	0.62	**–1.00**
FS109	85.46	14.54	84.78	15.22	2	0	**2**	1.00	0.85	**1.00**
FS123	95.15	4.85	94.57	5.43	4	0	**4**	1.00	0.95	**1.00**
Overall	**86.67**	**13.33**	**82.74**	**17.26**	**98.11**	**1.89**	**53**	**0.98**	**0.85**	**0.81**

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Eastern Cape Karoo summer

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EM01	95.20	4.80	97.94	2.06	62	0	62	1.00	0.97	1.00
EM02	92.54	7.46	97.85	2.15	1	0	1	1.00	0.95	1.00
EP01	84.90	15.10	97.93	2.07	17	0	17	1.00	0.91	1.00
EP06	70.40	29.60	82.60	17.40	71	4	75	0.95	0.77	0.69
EP07	92.19	7.81	97.38	2.62	367	0	367	1.00	0.95	1.00
EP09	61.70	38.30	72.46	27.54	14	0	14	1.00	0.67	1.00
EP10	76.55	23.45	96.47	3.53	257	4	261	0.98	0.87	0.82
ES07	99.32	0.68	98.78	1.22	1	0	1	1.00	0.99	1.00
Overall	**85.45**	**14.55**	**94.13**	**5.87**	**99.00**	**1.00**	**798**	**0.99**	**0.90**	**0.84**

Eastern Cape Karoo winter

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
EM01	95.20	4.80	97.94	2.06	39	0	39	1.00	0.97	1.00
EP01	84.90	15.10	97.93	2.07	6	0	6	1.00	0.91	1.00
EP06	70.40	29.60	82.60	17.40	19	0	19	1.00	0.77	1.00
EP07	92.19	7.81	97.38	2.62	157	0	157	1.00	0.95	1.00
EP09	61.70	38.30	72.46	27.54	2	0	2	1.00	0.67	1.00
EP10	76.55	23.45	96.47	3.53	165	52	217	0.76	0.87	–0.34
ES03	96.82	3.18	95.30	4.70	2	0	2	1.00	0.96	1.00
Overall	**84.89**	**15.11**	**93.36**	**6.64**	**88.24**	**11.76**	**442**	**0.88**	**0.89**	**–0.04**

Eastern Karoo summer

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
NK011	99.26	0.74	100.00	0.00	2	0	2	1.00	1.00	1.00
NK012	98.48	1.52	99.85	0.15	5	0	5	1.00	0.99	1.00
NK013	99.19	0.81	100.00	0.00	13	0	13	1.00	1.00	1.00
NK021	97.79	2.21	99.96	0.04	31	0	31	1.00	0.99	1.00
NK022	90.81	9.19	100.00	0.00	6	0	6	1.00	0.95	1.00
NK023	91.01	8.99	100.00	0.00	12	0	12	1.00	0.96	1.00
NK031	97.54	2.46	100.00	0.00	46	0	46	1.00	0.99	1.00
NK032	98.40	1.60	100.00	0.00	16	0	16	1.00	0.99	1.00
NK033	99.91	0.09	100.00	0.00	11	0	11	1.00	1.00	1.00
NK041	98.71	1.29	100.00	0.00	18	0	18	1.00	0.99	1.00
NK042	97.91	2.09	100.00	0.00	24	0	24	1.00	0.99	1.00
NK044	99.83	0.17	100.00	0.00	25	0	25	1.00	1.00	1.00
NK061	99.96	0.04	100.00	0.00	14	0	14	1.00	1.00	1.00
NK062	100.00	0.00	100.00	0.00	17	1	18	0.94	1.00	–1.00
NK063	99.84	0.16	100.00	0.00	3	0	3	1.00	1.00	1.00
NK071	95.84	4.16	100.00	0.00	26	0	26	1.00	0.98	1.00
NK073	99.38	0.62	100.00	0.00	4	0	4	1.00	1.00	1.00
NK081	99.66	0.34	100.00	0.00	49	0	49	1.00	1.00	1.00
NK082	99.93	0.07	100.00	0.00	18	0	18	1.00	1.00	1.00
NK083	99.87	0.13	100.00	0.00	8	0	8	1.00	1.00	1.00
NK091	91.90	8.10	100.00	0.00	81	0	81	1.00	0.96	1.00
NK092	95.52	4.48	100.00	0.00	45	0	45	1.00	0.98	1.00
NK093	87.74	12.26	100.00	0.00	32	0	32	1.00	0.94	1.00
NK101	97.76	2.24	97.91	2.09	28	2	30	0.93	0.98	–0.53
NK102	99.70	0.30	99.69	0.31	34	0	34	1.00	1.00	1.00
NK142	99.33	0.67	99.74	0.26	14	0	14	1.00	1.00	1.00
NK143	99.96	0.04	100.00	0.00	1	0	1	1.00	1.00	1.00
NK151	99.94	0.06	100.00	0.00	121	0	121	1.00	1.00	1.00
NK171	99.93	0.07	100.00	0.00	13	0	13	1.00	1.00	1.00

NK172	99.65	0.35	99.89	0.11	3	0	3	1.00	1.00	1.00
NK181	98.19	1.81	98.70	1.30	47	0	47	1.00	0.98	1.00
NK182	94.73	5.27	96.73	3.27	54	0	54	1.00	0.96	1.00
NK183	96.15	3.85	96.71	3.29	5	3	8	0.63	0.96	–0.88
NK211	92.28	7.72	100.00	0.00	25	0	25	1.00	0.96	1.00
NK212	95.54	4.46	100.00	0.00	23	0	23	1.00	0.98	1.00
NK213	96.84	3.16	100.00	0.00	15	0	15	1.00	0.98	1.00
NK221	95.90	4.10	100.00	0.00	109	0	109	1.00	0.98	1.00
NK222	98.93	1.07	99.96	0.04	60	0	60	1.00	0.99	1.00
NK223	98.55	1.45	100.00	0.00	32	0	32	1.00	0.99	1.00
NK231	99.03	0.97	100.00	0.00	187	2	189	0.99	1.00	–0.37
NK232	96.42	3.58	100.00	0.00	74	1	75	0.99	0.98	0.15
NK233	98.59	1.41	100.00	0.00	63	0	63	1.00	0.99	1.00
NK261	98.56	1.44	100.00	0.00	5	0	5	1.00	0.99	1.00
NK262	99.71	0.29	100.00	0.00	1	0	1	1.00	1.00	1.00
NK263	91.43	8.57	92.74	7.26	7	0	7	1.00	0.92	1.00
NK312	97.95	2.05	99.94	0.06	4	0	4	1.00	0.99	1.00
NK313	99.95	0.05	100.00	0.00	1	0	1	1.00	1.00	1.00
NK321	92.39	7.61	99.94	0.06	2	0	2	1.00	0.96	1.00
NK322	97.33	2.67	100.00	0.00	8	0	8	1.00	0.99	1.00
NK323	96.11	3.89	99.97	0.03	4	0	4	1.00	0.98	1.00
NK331	97.41	2.59	98.95	1.05	41	0	41	1.00	0.98	1.00
NK332	94.14	5.86	100.00	0.00	7	0	7	1.00	0.97	1.00
NK333	99.82	0.18	100.00	0.00	2	0	2	1.00	1.00	1.00
NK341	99.29	0.71	99.31	0.69	5	0	5	1.00	0.99	1.00
NK342	98.39	1.61	98.29	1.71	1	0	1	1.00	0.98	1.00
NK343	98.62	1.38	98.58	1.42	3	0	3	1.00	0.99	1.00
NK351	99.82	0.18	99.97	0.03	3	0	3	1.00	1.00	1.00
NK353	99.96	0.04	100.00	0.00	1	0	1	1.00	1.00	1.00
NK362	97.45	2.55	100.00	0.00	7	0	7	1.00	0.99	1.00
NK363	99.39	0.61	100.00	0.00	1	0	1	1.00	1.00	1.00
NK391	83.63	16.37	99.93	0.07	9	0	9	1.00	0.92	1.00
NK392	87.45	12.55	96.61	3.39	1	0	1	1.00	0.92	1.00
NK393	99.00	1.00	100.00	0.00	6	0	6	1.00	1.00	1.00
NK431	99.14	0.86	100.00	0.00	94	0	94	1.00	1.00	1.00
NK451	86.08	13.92	99.98	0.02	15	0	15	1.00	0.93	1.00
Overall	97.00	3.00	99.56	0.44	99.45	0.55	1651	0.99	0.98	0.52

	Eastern Karoo winter									
	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
NK021	97.79	2.21	99.96	0.04	9	0	**9**	1.00	0.99	**1.00**
NK022	90.81	9.19	100.00	0.00	4	0	**4**	1.00	0.95	**1.00**
NK023	91.01	8.99	100.00	0.00	4	0	**4**	1.00	0.96	**1.00**
NK031	97.54	2.46	100.00	0.00	19	0	**19**	1.00	0.99	**1.00**
NK032	98.40	1.60	100.00	0.00	10	0	**10**	1.00	0.99	**1.00**
NK033	99.91	0.09	100.00	0.00	8	0	**8**	1.00	1.00	**1.00**
NK041	98.71	1.29	100.00	0.00	19	0	**19**	1.00	0.99	**1.00**
NK042	97.91	2.09	100.00	0.00	34	0	**34**	1.00	0.99	**1.00**
NK044	99.83	0.17	100.00	0.00	10	0	**10**	1.00	1.00	**1.00**
NK061	99.96	0.04	100.00	0.00	13	0	**13**	1.00	1.00	**1.00**
NK063	99.84	0.16	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK071	95.84	4.16	100.00	0.00	25	0	**25**	1.00	0.98	**1.00**
NK073	99.38	0.62	100.00	0.00	12	0	**12**	1.00	1.00	**1.00**
NK081	99.66	0.34	100.00	0.00	33	0	**33**	1.00	1.00	**1.00**
NK082	99.93	0.07	100.00	0.00	6	0	**6**	1.00	1.00	**1.00**
NK083	99.87	0.13	100.00	0.00	3	0	**3**	1.00	1.00	**1.00**
NK091	91.90	8.10	100.00	0.00	37	0	**37**	1.00	0.96	**1.00**
NK092	95.52	4.48	100.00	0.00	5	0	**5**	1.00	0.98	**1.00**
NK093	87.74	12.26	100.00	0.00	27	0	**27**	1.00	0.94	**1.00**
NK101	97.76	2.24	97.91	2.09	39	10	**49**	0.80	0.98	**–0.84**
NK102	99.70	0.30	99.69	0.31	41	0	**41**	1.00	1.00	**1.00**
NK111	97.08	2.92	100.00	0.00	5	0	**5**	1.00	0.99	**1.00**
NK112	99.00	1.00	100.00	0.00	2	0	**2**	1.00	0.99	**1.00**
NK142	99.33	0.67	99.74	0.26	8	0	**8**	1.00	1.00	**1.00**
NK151	99.94	0.06	100.00	0.00	52	0	**52**	1.00	1.00	**1.00**
NK171	99.93	0.07	100.00	0.00	16	0	**16**	1.00	1.00	**1.00**
NK172	99.65	0.35	99.89	0.11	6	0	**6**	1.00	1.00	**1.00**
NK181	98.19	1.81	98.70	1.30	14	0	**14**	1.00	0.98	**1.00**
NK182	94.73	5.27	96.73	3.27	37	0	**37**	1.00	0.96	**1.00**
NK183	96.15	3.85	96.71	3.29	2	1	**3**	0.67	0.96	**–0.86**
NK211	92.28	7.72	100.00	0.00	12	0	**12**	1.00	0.96	**1.00**
NK212	95.54	4.46	100.00	0.00	21	0	**21**	1.00	0.98	**1.00**
NK213	96.84	3.16	100.00	0.00	16	0	**16**	1.00	0.98	**1.00**
NK221	95.90	4.10	100.00	0.00	80	0	**80**	1.00	0.98	**1.00**
NK222	98.93	1.07	99.96	0.04	46	0	**46**	1.00	0.99	**1.00**
NK223	98.55	1.45	100.00	0.00	31	0	**31**	1.00	0.99	**1.00**
NK231	99.03	0.97	100.00	0.00	69	0	**69**	1.00	1.00	**1.00**
NK232	96.42	3.58	100.00	0.00	49	0	**49**	1.00	0.98	**1.00**
NK233	98.59	1.41	100.00	0.00	48	0	**48**	1.00	0.99	**1.00**
NK261	98.56	1.44	100.00	0.00	18	0	**18**	1.00	0.99	**1.00**
NK262	99.71	0.29	100.00	0.00	11	0	**11**	1.00	1.00	**1.00**
NK263	91.43	8.57	92.74	7.26	25	0	**25**	1.00	0.92	**1.00**
NK312	97.95	2.05	99.94	0.06	2	0	**2**	1.00	0.99	**1.00**
NK313	99.95	0.05	100.00	0.00	2	0	**2**	1.00	1.00	**1.00**
NK323	96.11	3.89	99.97	0.03	1	0	**1**	1.00	0.98	**1.00**
NK331	97.41	2.59	98.95	1.05	3	0	**3**	1.00	0.98	**1.00**
NK332	94.14	5.86	100.00	0.00	2	0	**2**	1.00	0.97	**1.00**
NK341	99.29	0.71	99.31	0.69	4	0	**4**	1.00	0.99	**1.00**
NK343	98.62	1.38	98.58	1.42	1	0	**1**	1.00	0.99	**1.00**
NK351	99.82	0.18	99.97	0.03	5	0	**5**	1.00	1.00	**1.00**
NK361	97.27	2.73	100.00	0.00	1	0	**1**	1.00	0.99	**1.00**
NK362	97.45	2.55	100.00	0.00	6	0	**6**	1.00	0.99	**1.00**
NK363	99.39	0.61	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK371	98.82	1.18	99.24	0.76	1	0	**1**	1.00	0.99	**1.00**
NK373	99.80	0.20	100.00	0.00	4	0	**4**	1.00	1.00	**1.00**
NK391	83.63	16.37	99.93	0.07	2	0	**2**	1.00	0.92	**1.00**
NK393	99.00	1.00	100.00	0.00	7	0	**7**	1.00	1.00	**1.00**
NK431	99.14	0.86	100.00	0.00	104	0	**104**	1.00	1.00	**1.00**

NK451	86.08	13.92	99.98	0.02	9	0	**9**	1.00	0.93	**1.00**
NK452	99.00	1.00	99.63	0.37	2	0	**2**	1.00	0.99	**1.00**
Overall	**97.10**	**2.90**	**99.60**	**0.40**	**99.00**	**1.00**	**1100**	**0.99**	**0.98**	**0.25**

Gauteng summer

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
GB01	54.74	45.26	45.70	54.30	4	1	**5**	0.80	0.50	**0.60**
GB02	92.15	7.85	91.71	8.29	6	0	**6**	1.00	0.92	**1.00**
GB03	68.32	31.68	44.47	55.53	1	4	**5**	0.20	0.56	**–0.68**
GB05	97.41	2.59	98.07	1.93	5	0	**5**	1.00	0.98	**1.00**
GB06	46.87	53.13	39.45	60.55	2	0	**2**	1.00	0.43	**1.00**
GC01	96.20	3.80	93.59	6.41	167	0	**167**	1.00	0.95	**1.00**
GC02	55.89	44.11	41.64	58.36	32	0	**32**	1.00	0.49	**1.00**
GC03	86.28	13.72	75.00	25.00	120	4	**124**	0.97	0.81	**0.76**
GC04	61.97	38.03	49.44	50.56	48	1	**49**	0.98	0.56	**0.95**
GC05	55.34	44.66	42.75	57.25	48	4	**52**	0.92	0.49	**0.85**
GD01	65.27	34.73	49.58	50.42	0	2	**2**	0.00	0.57	**–1.00**
GD02	53.19	46.81	40.65	59.35	3	0	**3**	1.00	0.47	**1.00**
GD04	61.05	38.95	47.26	52.74	2	1	**3**	0.67	0.54	**0.26**
GH01	63.01	36.99	54.69	45.31	1	0	**1**	1.00	0.59	**1.00**
GH02	57.14	42.86	48.26	51.74	2	0	**2**	1.00	0.53	**1.00**
GH03	72.38	27.62	50.08	49.92	36	6	**42**	0.86	0.61	**0.58**
GH04	45.48	54.52	35.43	64.57	23	1	**24**	0.96	0.40	**0.94**
GH05	96.55	3.45	95.20	4.80	17	0	**17**	1.00	0.96	**1.00**
GM01	81.29	18.71	67.68	32.32	9	0	**9**	1.00	0.74	**1.00**
GW02	81.18	18.82	66.87	33.13	9	2	**11**	0.82	0.74	**0.22**
Overall	**67.02**	**32.98**	**55.08**	**44.92**	**95.37**	**4.63**	**561**	**0.95**	**0.61**	**0.86**

Gauteng winter

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
GB01	54.74	45.26	45.70	54.30	14	6	**20**	0.70	0.50	**0.40**
GB02	92.15	7.85	91.71	8.29	6	0	**6**	1.00	0.92	**1.00**
GB03	68.32	31.68	44.47	55.53	2	0	**2**	1.00	0.56	**1.00**
GB05	97.41	2.59	98.07	1.93	11	4	**15**	0.73	0.98	**–0.88**
GC01	96.20	3.80	93.59	6.41	48	38	**86**	0.56	0.95	**–0.87**
GC02	55.89	44.11	41.64	58.36	2	1	**3**	0.67	0.49	**0.36**
GC03	86.28	13.72	75.00	25.00	38	6	**44**	0.86	0.81	**0.21**
GC04	61.97	38.03	49.44	50.56	8	14	**22**	0.36	0.56	**–0.38**
GC05	55.34	44.66	42.75	57.25	16	2	**18**	0.89	0.49	**0.79**
GD02	53.19	46.81	40.65	59.35	1	0	**1**	1.00	0.47	**1.00**
GD03	87.67	12.33	76.45	23.55	0	8	**8**	0.00	0.82	**–1.00**
GH01	63.01	36.99	54.69	45.31	17	2	**19**	0.89	0.59	**0.71**
GH02	57.14	42.86	48.26	51.74	2	2	**4**	0.50	0.53	**–0.05**
GH03	72.38	27.62	50.08	49.92	16	3	**19**	0.84	0.61	**0.54**
GH04	45.48	54.52	35.43	64.57	12	1	**13**	0.92	0.40	**0.89**
GH05	96.55	3.45	95.20	4.80	13	12	**25**	0.52	0.96	**–0.91**
GM01	81.29	18.71	67.68	32.32	3	0	**3**	1.00	0.74	**1.00**
GW02	81.18	18.82	66.87	33.13	2	0	**2**	1.00	0.74	**1.00**
Overall	**69.45**	**30.55**	**57.70**	**42.30**	**68.06**	**31.94**	**310**	**0.68**	**0.64**	**0.10**

North-eastern Free State summer

Route	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FN03	47.99	52.01	28.23	71.77	0	2	**2**	0.00	0.38	**–1.00**
FN30	96.21	3.79	88.59	11.41	2	0	**2**	1.00	0.92	**1.00**
FN37	69.10	30.90	54.10	45.90	25	8	**33**	0.76	0.62	**0.32**
FN40	43.40	56.60	29.73	70.27	10	5	**15**	0.67	0.37	**0.55**
FN41	62.46	37.54	48.34	51.66	53	10	**63**	0.84	0.55	**0.62**
FN48	67.34	32.66	52.70	47.30	12	0	**12**	1.00	0.60	**1.00**
FN50	64.31	35.69	53.47	46.53	0	1	**1**	0.00	0.59	**–1.00**
FN51	55.68	44.32	39.34	60.66	2	0	**2**	1.00	0.48	**1.00**
FN54	56.37	43.63	46.78	53.22	0	1	**1**	0.00	0.52	**–1.00**
FN60	67.90	32.10	55.79	44.21	760	28	**788**	0.96	0.62	**0.89**
FN61	57.15	42.85	40.73	59.27	1	0	**1**	1.00	0.49	**1.00**
FN62	69.16	30.84	55.34	44.66	5	2	**7**	0.71	0.62	**0.21**
Overall	**62.98**	**37.02**	**49.32**	**50.68**	**93.85**	**6.15**	**927**	**0.94**	**0.56**	**0.85**

North-eastern Free State winter

Route	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
FN02	50.45	49.55	38.98	61.02	0	3	**3**	0.00	0.45	**–1.00**
FN03	47.99	52.01	28.23	71.77	1	7	**8**	0.13	0.38	**–0.62**
FN04	68.43	31.57	55.68	44.32	1	0	**1**	1.00	0.62	**1.00**
FN06	63.63	36.37	48.19	51.81	4	0	**4**	1.00	0.56	**1.00**
FN11	60.11	39.89	48.52	51.48	0	2	**2**	0.00	0.54	**–1.00**
FN13	76.21	23.79	61.25	38.75	3	2	**5**	0.60	0.69	**–0.19**
FN15	72.02	27.98	60.81	39.19	4	0	**4**	1.00	0.66	**1.00**
FN25	84.78	15.22	72.42	27.58	8	0	**8**	1.00	0.79	**1.00**
FN28	93.20	6.80	80.73	19.27	3	0	**3**	1.00	0.87	**1.00**
FN36	34.14	65.86	16.87	83.13	2	0	**2**	1.00	0.26	**1.00**
FN37	69.10	30.90	54.10	45.90	19	13	**32**	0.59	0.62	**–0.05**
FN39	50.88	49.12	38.22	61.78	0	1	**1**	0.00	0.45	**–1.00**
FN40	43.40	56.60	29.73	70.27	1	1	**2**	0.50	0.37	**0.27**
FN41	62.46	37.54	48.34	51.66	44	3	**47**	0.94	0.55	**0.84**
FN44	53.80	46.20	34.68	65.32	1	0	**1**	1.00	0.44	**1.00**
FN47	69.15	30.85	59.52	40.48	2	0	**2**	1.00	0.64	**1.00**
FN48	67.34	32.66	52.70	47.30	13	6	**19**	0.68	0.60	**0.18**
FN60	67.90	32.10	55.79	44.21	389	28	**417**	0.93	0.62	**0.79**
FN61	57.15	42.85	40.73	59.27	9	0	**9**	1.00	0.49	**1.00**
FN62	69.16	30.84	55.34	44.66	5	0	**5**	1.00	0.62	**1.00**
Overall	**62.97**	**37.03**	**48.87**	**51.13**	**88.52**	**11.48**	**575**	**0.89**	**0.56**	**0.72**

North-western Free State summer

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
FW01	47.46	52.54	31.67	68.33	0	1	**1**	0.00	0.40	**–1.00**
FW02	53.03	46.97	42.02	57.98	15	2	**17**	0.88	0.48	**0.78**
FW03	48.90	51.10	35.75	64.25	4	1	**5**	0.80	0.42	**0.69**
FW08	79.41	20.59	68.90	31.10	30	3	**33**	0.91	0.74	**0.55**
FW11	43.34	56.66	32.65	67.35	1	0	**1**	1.00	0.38	**1.00**
FW13	90.70	9.30	60.14	39.86	6	2	**8**	0.75	0.75	**–0.01**
FW15	68.51	31.49	61.96	38.04	6	1	**7**	0.86	0.65	**0.52**
FW16	54.38	45.62	43.32	56.68	66	3	**69**	0.96	0.49	**0.92**
FW18	85.16	14.84	73.59	26.41	706	3	**709**	1.00	0.79	**0.97**
FW19	48.94	51.06	31.43	68.57	53	1	**54**	0.98	0.40	**0.97**
FW22	83.66	16.34	68.90	31.10	36	6	**42**	0.86	0.76	**0.30**
FW23	66.61	33.39	53.98	46.02	54	0	**54**	1.00	0.60	**1.00**
FW26	72.40	27.60	51.09	48.91	113	8	**121**	0.93	0.62	**0.79**
FW27	69.20	30.80	48.37	51.63	11	2	**13**	0.85	0.59	**0.59**
FW28	79.01	20.99	60.65	39.35	141	0	**141**	1.00	0.70	**1.00**
FW31	77.26	22.74	52.58	47.42	100	27	**127**	0.79	0.65	**0.33**
FW33	66.70	33.30	45.88	54.12	41	1	**42**	0.98	0.56	**0.94**
FW34	68.72	31.28	47.41	52.59	632	2	**634**	1.00	0.58	**0.99**
FW35	50.82	49.18	27.58	72.42	12	0	**12**	1.00	0.39	**1.00**
FW36	50.51	49.49	36.57	63.43	347	6	**353**	0.98	0.44	**0.97**
FW37	58.21	41.79	37.69	62.31	7	0	**7**	1.00	0.48	**1.00**
FW38	36.90	63.10	18.94	81.06	47	0	**47**	1.00	0.28	**1.00**
FW39	65.01	34.99	41.34	58.66	21	18	**39**	0.54	0.53	**0.01**
FW40	37.86	62.14	15.82	84.18	0	3	**3**	0.00	0.27	**–1.00**
FW41	55.05	44.95	31.26	68.74	2	0	**2**	1.00	0.43	**1.00**
FW42	55.80	44.20	32.26	67.74	25	4	**29**	0.86	0.44	**0.78**
FW43	65.94	34.06	41.90	58.10	115	2	**117**	0.98	0.54	**0.96**
FW44	30.49	69.51	13.01	86.99	0	3	**3**	0.00	0.22	**–1.00**
FW45	63.68	36.32	49.52	50.48	65	0	**65**	1.00	0.57	**1.00**
FW46	90.77	9.23	77.68	22.32	303	0	**303**	1.00	0.84	**1.00**
FW47	89.03	10.97	69.47	30.53	149	5	**154**	0.97	0.79	**0.77**
FW50	51.67	48.33	36.90	63.10	55	50	**105**	0.52	0.44	**0.16**
FW51	73.78	26.22	66.79	33.21	809	0	**809**	1.00	0.70	**1.00**
FW52	42.18	57.82	28.60	71.40	37	36	**73**	0.51	0.35	**0.30**
FW53	71.83	28.17	58.03	41.97	249	13	**262**	0.95	0.65	**0.82**
FW54	40.03	59.97	20.41	79.59	17	12	**29**	0.59	0.30	**0.53**
FW55	45.42	54.58	26.89	73.11	35	3	**38**	0.92	0.36	**0.91**
FW56	74.66	25.34	54.39	45.61	43	0	**43**	1.00	0.65	**1.00**
FW57	57.48	42.52	41.97	58.03	88	0	**88**	1.00	0.50	**1.00**
FW58	82.88	17.12	65.69	34.31	138	0	**138**	1.00	0.74	**1.00**
FW59	50.95	49.05	29.21	70.79	42	4	**46**	0.91	0.40	**0.88**
FW60	51.97	48.03	39.93	60.07	4	1	**5**	0.80	0.46	**0.65**
FW61	78.30	21.70	70.06	29.94	131	0	**131**	1.00	0.74	**1.00**
FW62	59.43	40.57	44.03	55.97	6	0	**6**	1.00	0.52	**1.00**
Overall	**61.95**	**38.05**	**45.01**	**54.99**	**95.53**	**4.47**	**4985**	**0.96**	**0.53**	**0.90**

	North-western Free State winter									
	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
FW02	53.03	46.97	42.02	57.98	43	20	**63**	0.68	0.48	**0.41**
FW04	60.38	39.62	46.07	53.93	13	1	**14**	0.93	0.53	**0.84**
FW05	64.54	35.46	55.35	44.65	1	0	**1**	1.00	0.60	**1.00**
FW08	79.41	20.59	68.90	31.10	22	1	**23**	0.96	0.74	**0.77**
FW13	90.70	9.30	60.14	39.86	21	0	**21**	1.00	0.75	**1.00**
FW15	68.51	31.49	61.96	38.04	29	1	**30**	0.97	0.65	**0.88**
FW16	54.38	45.62	43.32	56.68	13	1	**14**	0.93	0.49	**0.86**
FW18	85.16	14.84	73.59	26.41	486	13	**499**	0.97	0.79	**0.81**
FW19	48.94	51.06	31.43	68.57	47	0	**47**	1.00	0.40	**1.00**
FW20	45.02	54.98	25.81	74.19	11	0	**11**	1.00	0.35	**1.00**
FW21	49.51	50.49	33.97	66.03	14	0	**14**	1.00	0.42	**1.00**
FW22	83.66	16.34	68.90	31.10	18	0	**18**	1.00	0.76	**1.00**
FW23	66.61	33.39	53.98	46.02	47	1	**48**	0.98	0.60	**0.94**
FW26	72.40	27.60	51.09	48.91	76	2	**78**	0.97	0.62	**0.92**
FW27	69.20	30.80	48.37	51.63	0	3	**3**	0.00	0.59	**–1.00**
FW28	79.01	20.99	60.65	39.35	106	8	**114**	0.93	0.70	**0.70**
FW29	44.09	55.91	20.99	79.01	18	3	**21**	0.86	0.33	**0.85**
FW30	46.50	53.50	23.23	76.77	4	0	**4**	1.00	0.35	**1.00**
FW31	77.26	22.74	52.58	47.42	67	11	**78**	0.86	0.65	**0.53**
FW33	66.70	33.30	45.88	54.12	47	4	**51**	0.92	0.56	**0.80**
FW34	68.72	31.28	47.41	52.59	565	0	**565**	1.00	0.58	**1.00**
FW35	50.82	49.18	27.58	72.42	4	0	**4**	1.00	0.39	**1.00**
FW36	50.51	49.49	36.57	63.43	180	6	**186**	0.97	0.44	**0.95**
FW37	58.21	41.79	37.69	62.31	48	0	**48**	1.00	0.48	**1.00**
FW38	36.90	63.10	18.94	81.06	0	6	**6**	0.00	0.28	**–1.00**
FW39	65.01	34.99	41.34	58.66	25	12	**37**	0.68	0.53	**0.29**
FW41	55.05	44.95	31.26	68.74	2	0	**2**	1.00	0.43	**1.00**
FW42	55.80	44.20	32.26	67.74	22	0	**22**	1.00	0.44	**1.00**
FW43	65.94	34.06	41.90	58.10	97	21	**118**	0.82	0.54	**0.60**
FW45	63.68	36.32	49.52	50.48	53	6	**59**	0.90	0.57	**0.74**
FW46	90.77	9.23	77.68	22.32	82	1	**83**	0.99	0.84	**0.88**
FW47	89.03	10.97	69.47	30.53	74	0	**74**	1.00	0.79	**1.00**
FW50	51.67	48.33	36.90	63.10	79	10	**89**	0.89	0.44	**0.82**
FW51	73.78	26.22	66.79	33.21	549	4	**553**	0.99	0.70	**0.97**
FW52	42.18	57.82	28.60	71.40	21	21	**42**	0.50	0.35	**0.29**
FW53	71.83	28.17	58.03	41.97	201	21	**222**	0.91	0.65	**0.68**
FW54	40.03	59.97	20.41	79.59	13	1	**14**	0.93	0.30	**0.94**
FW55	45.42	54.58	26.89	73.11	39	3	**42**	0.93	0.36	**0.92**
FW56	74.66	25.34	54.39	45.61	43	0	**43**	1.00	0.65	**1.00**
FW57	57.48	42.52	41.97	58.03	113	0	**113**	1.00	0.50	**1.00**
FW58	82.88	17.12	65.69	34.31	111	9	**120**	0.93	0.74	**0.62**
FW59	50.95	49.05	29.21	70.79	30	0	**30**	1.00	0.40	**1.00**
FW60	51.97	48.03	39.93	60.07	2	0	**2**	1.00	0.46	**1.00**
FW61	78.30	21.70	70.06	29.94	103	0	**103**	1.00	0.74	**1.00**
FW62	59.43	40.57	44.03	55.97	27	0	**27**	1.00	0.52	**1.00**
Overall	**62.92**	**37.08**	**45.78**	**54.22**	**94.94**	**5.06**	**3756**	**0.95**	**0.54**	**0.88**

Southern Free State summer

	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	Natural	Transf.	Natural	Transf.	Natural	Transf.	Total	*r*	*p*	*D*
V01	91.35	8.65	97.92	2.08	62	0	62	1.00	0.95	1.00
FS01	90.69	9.31	91.18	8.82	4	0	4	1.00	0.91	1.00
FS02	97.80	2.20	98.35	1.65	2	0	2	1.00	0.98	1.00
FS03	98.60	1.40	98.34	1.66	3	0	3	1.00	0.98	1.00
FS04	99.38	0.62	98.38	1.62	23	0	23	1.00	0.99	1.00
FS05	99.82	0.18	99.27	0.73	10	0	10	1.00	1.00	1.00
FS06	99.72	0.28	98.50	1.50	220	0	220	1.00	0.99	1.00
FS07	97.95	2.05	97.20	2.80	138	4	142	0.97	0.98	–0.08
FS08	97.20	2.80	97.07	2.93	80	0	80	1.00	0.97	1.00
FS09	98.20	1.80	97.81	2.19	228	8	236	0.97	0.98	–0.27
FS10	94.30	5.70	95.95	4.05	39	0	39	1.00	0.95	1.00
FS11	96.98	3.02	97.94	2.06	30	0	30	1.00	0.97	1.00
FS12	96.33	3.67	96.12	3.88	525	0	525	1.00	0.96	1.00
FS13	99.49	0.51	98.87	1.13	32	0	32	1.00	0.99	1.00
FS14	99.92	0.08	98.90	1.10	402	0	402	1.00	0.99	1.00
FS15	99.09	0.91	99.36	0.64	190	1	191	0.99	0.99	0.20
FS16	92.52	7.48	90.86	9.14	68	1	69	0.99	0.92	0.72
FS17	94.90	5.10	94.57	5.43	588	0	588	1.00	0.95	1.00
FS18	95.76	4.24	95.73	4.27	581	2	583	1.00	0.96	0.86
FS19	82.64	17.36	74.03	25.97	573	31	604	0.95	0.78	0.67
FS20	81.12	18.88	73.08	26.92	624	30	654	0.95	0.77	0.72
FS21	86.31	13.69	76.46	23.54	538	9	547	0.98	0.81	0.86
FS22	84.81	15.19	85.32	14.68	118	10	128	0.92	0.85	0.35
FS23	94.58	5.42	94.45	5.55	17	6	23	0.74	0.95	–0.72
FS24	96.18	3.82	97.18	2.82	69	0	69	1.00	0.97	1.00
FS25	96.69	3.31	97.70	2.30	41	1	42	0.98	0.97	0.08
FS26	94.80	5.20	95.17	4.83	26	0	26	1.00	0.95	1.00
FS27	97.10	2.90	97.66	2.34	93	1	94	0.99	0.97	0.43
FS28	97.24	2.76	92.07	7.93	74	3	77	0.96	0.95	0.16
FS29	98.34	1.66	96.27	3.73	192	17	209	0.92	0.97	–0.52
FS30	78.52	21.48	72.16	27.84	312	11	323	0.97	0.75	0.81
FS31	91.10	8.90	89.07	10.93	212	6	218	0.97	0.90	0.59
FS32	94.46	5.54	94.92	5.08	20	0	20	1.00	0.95	1.00
FS33	94.31	5.69	95.75	4.25	22	0	22	1.00	0.95	1.00
FS34	94.44	5.56	94.73	5.27	38	0	38	1.00	0.95	1.00
FS35	82.89	17.11	73.74	26.26	378	13	391	0.97	0.78	0.78
FS36	68.59	31.41	58.71	41.29	6	0	6	1.00	0.64	1.00
FS37	84.98	15.02	74.85	25.15	16	0	16	1.00	0.80	1.00
FS38	74.42	25.58	58.49	41.51	88	9	97	0.91	0.66	0.66
FS39	66.18	33.82	65.86	34.14	54	0	54	1.00	0.66	1.00
FS40	93.52	6.48	92.64	7.36	286	2	288	0.99	0.93	0.83
FS41	68.31	31.69	68.40	31.60	46	0	46	1.00	0.68	1.00
FS42	77.79	22.21	87.50	12.50	256	2	258	0.99	0.83	0.93
FS43	87.06	12.94	67.98	32.02	827	1	828	1.00	0.78	0.99
FS44	90.63	9.37	81.27	18.73	6	0	6	1.00	0.86	1.00
FS45	86.01	13.99	79.77	20.23	59	9	68	0.87	0.83	0.15
FS46	51.68	48.32	42.30	57.70	58	4	62	0.94	0.47	0.88
FS47	80.97	19.03	69.04	30.96	401	2	403	1.00	0.75	0.97
FS48	87.25	12.75	82.60	17.40	501	6	507	0.99	0.85	0.87
FS49	50.05	49.95	43.33	56.67	82	4	86	0.95	0.47	0.92
FS50	80.98	19.02	77.77	22.23	14	0	14	1.00	0.79	1.00
FS51	94.23	5.77	93.48	6.52	201	0	201	1.00	0.94	1.00
FS52	77.46	22.54	72.40	27.60	65	11	76	0.86	0.75	0.33
FS53	65.51	34.49	54.64	45.36	95	15	110	0.86	0.60	0.62
FS54	84.09	15.91	74.39	25.61	656	4	660	0.99	0.79	0.95
FS55	96.44	3.56	96.61	3.39	456	0	456	1.00	0.97	1.00
FS56	87.88	12.12	88.13	11.87	974	40	1014	0.96	0.88	0.54
FS57	88.76	11.24	79.49	20.51	83	1	84	0.99	0.84	0.88

FS58	87.24	12.76	84.70	15.30	484	1	**485**	1.00	0.86	**0.97**
FS59	82.52	17.48	80.21	19.79	32	0	**32**	1.00	0.81	**1.00**
FS60	80.73	19.27	78.62	21.38	184	0	**184**	1.00	0.80	**1.00**
FS62	93.89	6.11	94.03	5.97	131	0	**131**	1.00	0.94	**1.00**
FS65	79.08	20.92	70.36	29.64	329	46	**375**	0.88	0.75	**0.42**
FS66	91.34	8.66	82.98	17.02	127	0	**127**	1.00	0.87	**1.00**
FS67	92.87	7.13	85.43	14.57	167	2	**169**	0.99	0.89	**0.82**
FS68	85.77	14.23	75.78	24.22	161	0	**161**	1.00	0.81	**1.00**
FS69	87.80	12.20	83.11	16.89	56	0	**56**	1.00	0.85	**1.00**
FS70	81.93	18.07	75.54	24.46	25	13	**38**	0.66	0.79	**–0.32**
FS73	71.98	28.02	61.51	38.49	0	2	**2**	0.00	0.67	**–1.00**
FS76	93.59	6.41	92.77	7.23	3	0	**3**	1.00	0.93	**1.00**
FS77	87.69	12.31	87.55	12.45	46	5	**51**	0.90	0.88	**0.13**
FS78	90.15	9.85	91.85	8.15	10	0	**10**	1.00	0.91	**1.00**
FS79	87.12	12.88	84.63	15.37	320	4	**324**	0.99	0.86	**0.86**
FS80	90.01	9.99	90.59	9.41	13	0	**13**	1.00	0.90	**1.00**
FS81	71.11	28.89	65.92	34.08	1	5	**6**	0.17	0.69	**–0.83**
FS82	96.15	3.85	97.14	2.86	108	0	**108**	1.00	0.97	**1.00**
FS83	91.80	8.20	85.12	14.88	17	0	**17**	1.00	0.88	**1.00**
FS84	89.35	10.65	91.57	8.43	24	0	**24**	1.00	0.90	**1.00**
FS85	58.56	41.44	49.09	50.91	277	2	**279**	0.99	0.54	**0.98**
FS86	73.33	26.67	66.40	33.60	384	2	**386**	0.99	0.70	**0.98**
FS87	85.72	14.28	89.20	10.80	50	0	**50**	1.00	0.87	**1.00**
FS88	95.07	4.93	85.52	14.48	270	4	**274**	0.99	0.90	**0.76**
FS89	49.21	50.79	39.35	60.65	10	1	**11**	0.91	0.44	**0.85**
FS90	93.07	6.93	93.87	6.13	8	0	**8**	1.00	0.93	**1.00**
FS91	73.02	26.98	67.62	32.38	711	8	**719**	0.99	0.70	**0.95**
FS93	99.48	0.52	98.96	1.04	102	0	**102**	1.00	0.99	**1.00**
FS94	93.10	6.90	94.21	5.79	211	1	**212**	1.00	0.94	**0.87**
FS95	91.46	8.54	91.97	8.03	27	0	**27**	1.00	0.92	**1.00**
FS96	82.07	17.93	69.84	30.16	1	0	**1**	1.00	0.76	**1.00**
FS97	79.58	20.42	75.67	24.33	9	3	**12**	0.75	0.78	**–0.07**
FS98	99.68	0.32	99.06	0.94	3	0	**3**	1.00	0.99	**1.00**
FS99	49.94	50.06	42.02	57.98	158	13	**171**	0.92	0.46	**0.87**
FS100	99.12	0.88	98.06	1.94	9	0	**9**	1.00	0.99	**1.00**
FS101	89.84	10.16	90.27	9.73	9	0	**9**	1.00	0.90	**1.00**
FS102	97.73	2.27	98.37	1.63	61	0	**61**	1.00	0.98	**1.00**
FS103	69.42	30.58	60.69	39.31	230	9	**239**	0.96	0.65	**0.86**
FS104	73.66	26.34	50.29	49.71	386	5	**391**	0.99	0.62	**0.96**
FS105	98.80	1.20	98.62	1.38	39	0	**39**	1.00	0.99	**1.00**
FS106	60.48	39.52	44.84	55.16	166	5	**171**	0.97	0.53	**0.94**
FS107	59.07	40.93	46.86	53.14	0	6	**6**	0.00	0.53	**–1.00**
FS108	56.72	43.28	41.93	58.07	11	13	**24**	0.46	0.49	**–0.07**
FS109	85.46	14.54	84.78	15.22	11	0	**11**	1.00	0.85	**1.00**
FS110	91.87	8.13	83.29	16.71	304	22	**326**	0.93	0.88	**0.32**
FS111	90.13	9.87	81.11	18.89	309	3	**312**	0.99	0.86	**0.89**
FS112	79.75	20.25	71.81	28.19	464	6	**470**	0.99	0.76	**0.92**
FS113	84.43	15.57	74.60	25.40	53	7	**60**	0.88	0.80	**0.32**
FS114	76.35	23.65	65.84	34.16	99	0	**99**	1.00	0.71	**1.00**
FS115	82.42	17.58	73.12	26.88	25	0	**25**	1.00	0.78	**1.00**
FS116	62.86	37.14	54.66	45.34	302	2	**304**	0.99	0.59	**0.98**
FS117	94.56	5.44	96.59	3.41	122	0	**122**	1.00	0.96	**1.00**
FS118	99.80	0.20	99.00	1.00	165	0	**165**	1.00	0.99	**1.00**
FS119	69.45	30.55	66.03	33.97	362	53	**415**	0.87	0.68	**0.53**
FS120	67.81	32.19	55.21	44.79	499	11	**510**	0.98	0.62	**0.93**
FS121	83.91	16.09	70.44	29.56	106	0	**106**	1.00	0.77	**1.00**
FS122	47.83	52.17	40.44	59.56	95	9	**104**	0.91	0.44	**0.86**
FS123	95.15	4.85	94.57	5.43	4	0	**4**	1.00	0.95	**1.00**
FS124	97.57	2.43	98.21	1.79	18	0	**18**	1.00	0.98	**1.00**
Overall	**85.52**	**14.48**	**81.38**	**18.62**	**97.45**	**2.55**	**20637**	**0.97**	**0.83**	**0.77**

	Southern Free State winter									
	NLC2000 % land area		NLC2009 % land area		No. NBKs			Jacobs index		
Route	**Natural**	**Transf.**	**Natural**	**Transf.**	**Natural**	**Transf.**	**Total**	***r***	***p***	***D***
EV01	91.35	8.65	97.92	2.08	9	0	**9**	1.00	0.95	**1.00**
FS01	90.69	9.31	91.18	8.82	1	0	**1**	1.00	0.91	**1.00**
FS03	98.60	1.40	98.34	1.66	10	0	**10**	1.00	0.98	**1.00**
FS04	99.38	0.62	98.38	1.62	24	0	**24**	1.00	0.99	**1.00**
FS05	99.82	0.18	99.27	0.73	9	0	**9**	1.00	1.00	**1.00**
FS06	99.72	0.28	98.50	1.50	91	0	**91**	1.00	0.99	**1.00**
FS07	97.95	2.05	97.20	2.80	74	13	**87**	0.85	0.98	**–0.75**
FS08	97.20	2.80	97.07	2.93	39	0	**39**	1.00	0.97	**1.00**
FS09	98.20	1.80	97.81	2.19	125	0	**125**	1.00	0.98	**1.00**
FS10	94.30	5.70	95.95	4.05	14	0	**14**	1.00	0.95	**1.00**
FS11	96.98	3.02	97.94	2.06	21	0	**21**	1.00	0.97	**1.00**
FS12	96.33	3.67	96.12	3.88	214	6	**220**	0.97	0.96	**0.17**
FS13	99.49	0.51	98.87	1.13	14	0	**14**	1.00	0.99	**1.00**
FS14	99.92	0.08	98.90	1.10	254	1	**255**	1.00	0.99	**0.20**
FS15	99.09	0.91	99.36	0.64	132	15	**147**	0.90	0.99	**–0.87**
FS16	92.52	7.48	90.86	9.14	67	1	**68**	0.99	0.92	**0.72**
FS17	94.90	5.10	94.57	5.43	490	3	**493**	0.99	0.95	**0.80**
FS18	95.76	4.24	95.73	4.27	225	2	**227**	0.99	0.96	**0.67**
FS19	82.64	17.36	74.03	25.97	495	48	**543**	0.91	0.78	**0.48**
FS20	81.12	18.88	73.08	26.92	512	23	**535**	0.96	0.77	**0.74**
FS21	86.31	13.69	76.46	23.54	210	2	**212**	0.99	0.81	**0.92**
FS22	84.81	15.19	85.32	14.68	64	3	**67**	0.96	0.85	**0.58**
FS23	94.58	5.42	94.45	5.55	39	0	**39**	1.00	0.95	**1.00**
FS24	96.18	3.82	97.18	2.82	27	0	**27**	1.00	0.97	**1.00**
FS25	96.69	3.31	97.70	2.30	35	0	**35**	1.00	0.97	**1.00**
FS26	94.80	5.20	95.17	4.83	35	2	**37**	0.95	0.95	**–0.04**
FS27	97.10	2.90	97.66	2.34	70	5	**75**	0.93	0.97	**–0.45**
FS28	97.24	2.76	92.07	7.93	51	4	**55**	0.93	0.95	**–0.16**
FS29	98.34	1.66	96.27	3.73	156	0	**156**	1.00	0.97	**1.00**
FS30	78.52	21.48	72.16	27.84	240	8	**248**	0.97	0.75	**0.82**
FS31	91.10	8.90	89.07	10.93	70	1	**71**	0.99	0.90	**0.77**
FS32	94.46	5.54	94.92	5.08	14	0	**14**	1.00	0.95	**1.00**
FS33	94.31	5.69	95.75	4.25	10	0	**10**	1.00	0.95	**1.00**
FS34	94.44	5.56	94.73	5.27	3	0	**3**	1.00	0.95	**1.00**
FS35	82.89	17.11	73.74	26.26	178	15	**193**	0.92	0.78	**0.53**
FS36	68.59	31.41	58.71	41.29	7	0	**7**	1.00	0.64	**1.00**
FS37	84.98	15.02	74.85	25.15	4	2	**6**	0.67	0.80	**–0.33**
FS38	74.42	25.58	58.49	41.51	49	0	**49**	1.00	0.66	**1.00**
FS39	66.18	33.82	65.86	34.14	47	8	**55**	0.85	0.66	**0.50**
FS40	93.52	6.48	92.64	7.36	173	0	**173**	1.00	0.93	**1.00**
FS41	68.31	31.69	68.40	31.60	5	0	**5**	1.00	0.68	**1.00**
FS42	77.79	22.21	87.50	12.50	186	7	**193**	0.96	0.83	**0.70**
FS43	87.06	12.94	67.98	32.02	468	3	**471**	0.99	0.78	**0.96**
FS44	90.63	9.37	81.27	18.73	29	1	**30**	0.97	0.86	**0.65**
FS45	86.01	13.99	79.77	20.23	35	2	**37**	0.95	0.83	**0.57**
FS46	51.68	48.32	42.30	57.70	29	1	**30**	0.97	0.47	**0.94**
FS47	80.97	19.03	69.04	30.96	234	0	**234**	1.00	0.75	**1.00**
FS48	87.25	12.75	82.60	17.40	324	0	**324**	1.00	0.85	**1.00**
FS49	50.05	49.95	43.33	56.67	18	1	**19**	0.95	0.47	**0.91**
FS50	80.98	19.02	77.77	22.23	9	1	**10**	0.90	0.79	**0.40**
FS51	94.23	5.77	93.48	6.52	19	1	**20**	0.95	0.94	**0.11**
FS52	77.46	22.54	72.40	27.60	33	10	**43**	0.77	0.75	**0.05**
FS53	65.51	34.49	54.64	45.36	55	11	**66**	0.83	0.60	**0.54**
FS54	84.09	15.91	74.39	25.61	628	1	**629**	1.00	0.79	**0.99**
FS55	96.44	3.56	96.61	3.39	131	0	**131**	1.00	0.97	**1.00**
FS56	87.88	12.12	88.13	11.87	893	11	**904**	0.99	0.88	**0.83**
FS57	88.76	11.24	79.49	20.51	47	5	**52**	0.90	0.84	**0.28**
FS58	87.24	12.76	84.70	15.30	156	0	**156**	1.00	0.86	**1.00**

FS59	82.52	17.48	80.21	19.79	28	0	**28**	1.00	0.81	**1.00**
FS60	80.73	19.27	78.62	21.38	137	1	**138**	0.99	0.80	**0.94**
FS61	72.67	27.33	51.81	48.19	8	2	**10**	0.80	0.62	**0.42**
FS62	93.89	6.11	94.03	5.97	37	0	**37**	1.00	0.94	**1.00**
FS63	92.72	7.28	83.40	16.60	16	5	**21**	0.76	0.88	**–0.39**
FS64	94.75	5.25	84.61	15.39	20	0	**20**	1.00	0.90	**1.00**
FS65	79.08	20.92	70.36	29.64	187	9	**196**	0.95	0.75	**0.75**
FS66	91.34	8.66	82.98	17.02	95	7	**102**	0.93	0.87	**0.33**
FS67	92.87	7.13	85.43	14.57	51	32	**83**	0.61	0.89	**–0.68**
FS68	85.77	14.23	75.78	24.22	153	4	**157**	0.97	0.81	**0.80**
FS69	87.80	12.20	83.11	16.89	48	0	**48**	1.00	0.85	**1.00**
FS70	81.93	18.07	75.54	24.46	24	10	**34**	0.71	0.79	**–0.21**
FS73	71.98	28.02	61.51	38.49	7	0	**7**	1.00	0.67	**1.00**
FS76	93.59	6.41	92.77	7.23	6	0	**6**	1.00	0.93	**1.00**
FS77	87.69	12.31	87.55	12.45	78	0	**78**	1.00	0.88	**1.00**
FS78	90.15	9.85	91.85	8.15	3	0	**3**	1.00	0.91	**1.00**
FS79	87.12	12.88	84.63	15.37	191	0	**191**	1.00	0.86	**1.00**
FS80	90.01	9.99	90.59	9.41	7	0	**7**	1.00	0.90	**1.00**
FS81	71.11	28.89	65.92	34.08	19	0	**19**	1.00	0.69	**1.00**
FS82	96.15	3.85	97.14	2.86	33	24	**57**	0.58	0.97	**–0.91**
FS83	91.80	8.20	85.12	14.88	26	0	**26**	1.00	0.88	**1.00**
FS84	89.35	10.65	91.57	8.43	44	0	**44**	1.00	0.90	**1.00**
FS85	58.56	41.44	49.09	50.91	96	2	**98**	0.98	0.54	**0.95**
FS86	73.33	26.67	66.40	33.60	158	14	**172**	0.92	0.70	**0.66**
FS87	85.72	14.28	89.20	10.80	7	0	**7**	1.00	0.87	**1.00**
FS88	95.07	4.93	85.52	14.48	171	6	**177**	0.97	0.90	**0.51**
FS90	93.07	6.93	93.87	6.13	11	0	**11**	1.00	0.93	**1.00**
FS91	73.02	26.98	67.62	32.38	470	8	**478**	0.98	0.70	**0.92**
FS92	83.97	16.03	75.42	24.58	2	0	**2**	1.00	0.80	**1.00**
FS93	99.48	0.52	98.96	1.04	40	0	**40**	1.00	0.99	**1.00**
FS94	93.10	6.90	94.21	5.79	53	0	**53**	1.00	0.94	**1.00**
FS95	91.46	8.54	91.97	8.03	28	0	**28**	1.00	0.92	**1.00**
FS96	82.07	17.93	69.84	30.16	3	3	**6**	0.50	0.76	**–0.52**
FS97	79.58	20.42	75.67	24.33	29	3	**32**	0.91	0.78	**0.47**
FS98	99.68	0.32	99.06	0.94	11	0	**11**	1.00	0.99	**1.00**
FS99	49.94	50.06	42.02	57.98	77	4	**81**	0.95	0.46	**0.92**
FS100	99.12	0.88	98.06	1.94	11	0	**11**	1.00	0.99	**1.00**
FS101	89.84	10.16	90.27	9.73	2	0	**2**	1.00	0.90	**1.00**
FS102	97.73	2.27	98.37	1.63	32	0	**32**	1.00	0.98	**1.00**
FS103	69.42	30.58	60.69	39.31	151	9	**160**	0.94	0.65	**0.80**
FS104	73.66	26.34	50.29	49.71	189	0	**189**	1.00	0.62	**1.00**
FS105	98.80	1.20	98.62	1.38	17	0	**17**	1.00	0.99	**1.00**
FS106	60.48	39.52	44.84	55.16	155	8	**163**	0.95	0.53	**0.89**
FS108	56.72	43.28	41.93	58.07	58	1	**59**	0.98	0.49	**0.97**
FS109	85.46	14.54	84.78	15.22	5	0	**5**	1.00	0.85	**1.00**
FS110	91.87	8.13	83.29	16.71	187	16	**203**	0.92	0.88	**0.25**
FS111	90.13	9.87	81.11	18.89	133	2	**135**	0.99	0.86	**0.84**
FS112	79.75	20.25	71.81	28.19	208	8	**216**	0.96	0.76	**0.79**
FS113	84.43	15.57	74.60	25.40	25	7	**32**	0.78	0.80	**–0.04**
FS114	76.35	23.65	65.84	34.16	84	3	**87**	0.97	0.71	**0.84**
FS115	82.42	17.58	73.12	26.88	57	1	**58**	0.98	0.78	**0.88**
FS116	62.86	37.14	54.66	45.34	158	0	**158**	1.00	0.59	**1.00**
FS117	94.56	5.44	96.59	3.41	92	0	**92**	1.00	0.96	**1.00**
FS118	99.80	0.20	99.00	1.00	79	0	**79**	1.00	0.99	**1.00**
FS119	69.45	30.55	66.03	33.97	177	21	**198**	0.89	0.68	**0.60**
FS120	67.81	32.19	55.21	44.79	219	5	**224**	0.98	0.62	**0.93**
FS121	83.91	16.09	70.44	29.56	65	1	**66**	0.98	0.77	**0.90**
FS122	47.83	52.17	40.44	59.56	58	1	**59**	0.98	0.44	**0.97**
FS123	95.15	4.85	94.57	5.43	7	0	**7**	1.00	0.95	**1.00**
FS124	97.57	2.43	98.21	1.79	7	0	**7**	1.00	0.98	**1.00**
Overall	**85.87**	**14.13**	**81.48**	**18.52**	**96.55**	**3.45**	**12585**	**0.97**	**0.84**	**0.69**

Table A4.3: Four sets of unequal weights used to produce the national population indices for (a) Blue Korhaans, (b) Karoo Korhaans and (c) Northern Black Korhaans. (The fifth set used equal weights, i.e. a weight of 0.14 for each precinct in the Blue Korhaan analysis, 0.25 in the Karoo Korhaan analysis and 0.20 in the Northern Black Korhaan analysis.) The area of a precinct was defined as that of all the quarter-degree grid cells the routes of the precinct entered. This was also the area for which reporting rates (RR, defined as the percentage of atlas lists from a precinct which reported the species in question) were extracted. Reporting rates from SABAP1 were used (Harrison et al. 1997). For the "Area*Griffioen RR" weightings, the conversion proposed by Griffioen (2001) was applied to the reporting rates (see text) before multiplying them by the precinct areas.

(a)

	Area			RR			Area*RR			Area*Griffioen RR		
		Weights			Weights			Weights			Weights	
Precinct	km^2	Summer	Winter	%	Summer	Winter	km^2*%	Summer	Winter	km^2*(–*ln*(1–RR))	Summer	Winter
Eastern Karoo	31929.79	0.16	0.15	20.98	0.12	0.11	669955.42	0.13	0.12	7519.35	0.12	0.11
Mpumalanga	15024.36		0.07	21.93		0.11	329465.37		0.06	3719.25		0.06
NE Eastern Cape	24196.92	0.12	0.11	32.13	0.18	0.16	777438.17	0.15	0.14	9378.02	0.15	0.14
NE Free State	25538.33	0.13	0.12	38.33	0.22	0.20	978839.04	0.19	0.18	12343.80	0.20	0.19
NW Free State	37650.92	0.19	0.18	16.20	0.09	0.08	610034.80	0.12	0.11	6655.39	0.11	0.10
S Free State	69379.59	0.35	0.33	27.78	0.16	0.14	1927210.75	0.37	0.34	22577.67	0.36	0.34
Wakkerstroom	7784.46	0.04	0.04	38.32	0.22	0.20	298283.12	0.06	0.05	3761.25	0.06	0.06

(b)

	Area		RR		Area*RR		Area*Griffioen RR	
Precinct	km^2	Weights	%	Weights	km^2*%	Weights	km^2*(–*ln*(1–RR))	Weights
Beaufort West	33402.90	0.26	70.79	0.46	2364475.16	0.49	41103.60	0.57
E Cape Karoo	31929.79	0.25	30.35	0.20	969148.33	0.20	11549.74	0.16
Eastern Karoo	25538.33	0.20	46.20	0.30	1179952.65	0.25	15832.65	0.22
Overberg	37650.92	0.29	7.78	0.05	293081.71	0.06	3051.18	0.04

(c)

	Area		RR		Area*RR		Area*Griffioen RR	
Precinct	km^2	Weights	%	Weights	km^2*%	Weights	km^2*(–*ln*(1–RR))	Weights
E Cape Karoo	33402.90	0.17	44.74	0.21	1494604.37	0.17	19814.83	0.16
Eastern Karoo	31929.79	0.16	58.78	0.27	1876864.72	0.21	28298.44	0.23
NE Free State	25538.33	0.13	14.09	0.06	359826.38	0.04	3878.40	0.03
NW Free State	37650.92	0.19	56.65	0.26	2132774.22	0.24	31467.56	0.26
S Free State	69379.59	0.35	43.41	0.20	3011782.73	0.34	39500.69	0.32

Table A4.4: National population index values calculated for the Blue Korhaan using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weights given in Table A4.3a and summing the results each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1998	1.27	1.17	1.17	1.10	1.09
1999	1.06	1.14	0.99	1.09	1.08
2000	0.55	0.60	0.58	0.61	0.62
2001	1.08	1.11	1.03	1.09	1.08
2002	0.80	0.80	0.83	0.83	0.83
2003	0.81	0.85	0.79	0.84	0.83
2004	0.94	0.96	0.98	1.00	1.00
2005	0.85	0.87	0.85	0.87	0.86
2006	0.92	0.91	0.91	0.90	0.90
2007	1.06	1.13	1.04	1.12	1.11
2008	0.90	0.95	0.90	0.95	0.94
2009	1.25	1.31	1.23	1.30	1.29
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1997	1.44	1.43	1.53	1.53	1.54
1998	1.95	1.99	2.09	2.14	2.16
1999	0.67	0.70	0.64	0.66	0.65
2000	1.37	1.43	1.34	1.38	1.36
2001	0.88	0.92	0.82	0.86	0.84
2002	0.77	0.76	0.77	0.76	0.76
2003	0.88	0.93	0.86	0.89	0.89
2004	0.92	0.94	0.91	0.93	0.93
2005	0.86	0.91	0.78	0.80	0.79
2006	1.27	1.24	1.15	1.13	1.12
2007	0.70	0.65	0.63	0.59	0.58
2008	0.74	0.73	0.70	0.69	0.69
2009	1.22	1.13	1.25	1.19	1.20
2010	1.00	1.00	1.00	1.00	1.00

Table A4.5: National population index values calculated for the Karoo Korhaan using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weights given in Table A4.3b and summing the results each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1996	0.73	0.74	0.77	0.78	0.79
1997	0.76	0.76	0.79	0.80	0.80
1998	0.82	0.81	0.83	0.82	0.83
1999	0.75	0.76	0.78	0.79	0.80
2000	0.88	0.89	0.84	0.85	0.84
2001	0.80	0.79	0.79	0.78	0.78
2002	0.95	0.97	1.01	1.03	1.04
2003	0.77	0.77	0.76	0.76	0.76
2004	0.47	0.47	0.41	0.41	0.39
2005	0.73	0.72	0.72	0.71	0.71
2006	1.10	1.12	1.15	1.17	1.18
2007	1.09	1.09	1.04	1.04	1.03
2008	0.52	0.52	0.52	0.53	0.53
2009	1.17	1.18	1.20	1.21	1.21
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1995	0.56	0.56	0.54	0.54	0.53
1996	0.59	0.58	0.56	0.55	0.55
1997	0.54	0.54	0.53	0.53	0.53
1998	0.58	0.58	0.55	0.55	0.54
1999	0.57	0.57	0.55	0.54	0.54
2000	0.71	0.70	0.60	0.58	0.56
2001	0.68	0.67	0.64	0.63	0.62
2002	0.50	0.50	0.50	0.50	0.50
2003	1.15	1.15	1.20	1.21	1.22
2004	0.72	0.71	0.71	0.70	0.70
2005	0.87	0.86	0.84	0.83	0.83
2006	0.65	0.64	0.55	0.54	0.52
2007	0.61	0.61	0.57	0.56	0.56
2008	1.42	1.44	1.46	1.47	1.48
2009	0.75	0.76	0.71	0.71	0.71
2010	1.00	1.00	1.00	1.00	1.00

Table A4.6: National population index values calculated for the Northern Black Korhaan using (a) summer and (b) winter CAR count totals. Index values were calculated by multiplying the bird densities (birds/100 km) for each precinct by the weights given in Table A4.3c and summing the results for each year. The yearly totals were converted to indices, using 2010 as the base year.

(a)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1998	0.62	0.56	0.63	0.58	0.58
1999	0.65	0.61	0.66	0.62	0.63
2000	0.88	0.94	0.85	0.92	0.91
2001	0.49	0.47	0.50	0.48	0.48
2002	0.35	0.33	0.35	0.33	0.33
2003	0.79	0.72	0.81	0.74	0.76
2004	1.25	1.20	1.27	1.23	1.24
2005	1.24	1.21	1.26	1.23	1.24
2006	1.42	1.39	1.45	1.42	1.43
2007	0.74	0.70	0.75	0.71	0.72
2008	1.38	1.33	1.41	1.37	1.38
2009	1.16	1.14	1.17	1.16	1.17
2010	1.00	1.00	1.00	1.00	1.00

(b)

Year	Equal	Area	RR	Area*RR	Area*Griffioen RR
1997	1.14	1.11	1.20	1.15	1.16
1998	1.14	1.11	1.20	1.15	1.16
1999	1.18	1.14	1.21	1.16	1.16
2000	0.90	0.89	0.90	0.89	0.89
2001	0.99	0.99	1.02	1.01	1.01
2002	0.55	0.56	0.56	0.57	0.57
2003	0.80	0.81	0.80	0.80	0.80
2004	1.20	1.21	1.20	1.21	1.21
2005	0.95	0.96	0.94	0.96	0.96
2006	1.02	1.01	1.04	1.03	1.03
2007	0.81	0.83	0.85	0.85	0.86
2008	1.38	1.41	1.47	1.47	1.48
2009	1.14	1.15	1.18	1.17	1.17
2010	1.00	1.00	1.00	1.00	1.00

Chapter 7

Synthesis

It is increasingly being recognized that nature conservation cannot simply be relegated to reserves, but where possible must be integrated with other land uses. The bustards, being in such direct conflict with man over the use of the land, are one of the most significant challenges in this regard

~ NJ Collar, 1996

Cranes often serve as "umbrella" and "flagship" species in conserving wetlands and grasslands around the world. As such, they draw attention to, and provide protection for, a broad array of species and ecosystems

~ CD Meine & GW Archibald, 1996

In this final chapter I provide a synthesis of the results of this study, and attempt to put them in the context of the larger conservation picture in southern Africa. I assess the coverage of the bustards as a group by the CAR project and by SABAP2 and provide recommendations for these projects. I also suggest topics for further research.

Synthesis of results

Results of all the CAR population trend analyses and SABAP comparison maps were summarised to give overall population trends for each species by province (Table 1). Habitat selection and habitat use results were also summarised by province. The provinces where the majority of trends were decreasing were those in the north-east of the country: Limpopo, Mpumalanga and KwaZulu-Natal. These provinces were characterised primarily by Grassland and Savanna vegetation (Figure 2 in Chapter 1), and were heavily transformed by afforestation, cultivation and land degradation (Figure 5b in Chapter 1). The North West was also heavily transformed, but only two of the focal species occurred there, one of which was decreasing (Blue Crane *Anthropoides paradiseus*). The Free State was heavily transformed but primarily by cultivation, which was apparently less deleterious for the species which occurred there than the transformation in the north-eastern provinces was; only one species (Karoo Korhaan *Eupodotis vigorsii*) showed a purely decreasing trend in this province, but its range only extended into the extreme south-west of the province (Figure 6b in Chapter 6). The Western Cape showed strikingly different trends to the other provinces for three species: Blue Crane (strongly increasing), Denham's Bustard *Neotis denhami* (increasing) and Southern Black Korhaan *Afrotis afra* (strongly decreasing). The large extent of land transformation in this province (predominantly cultivation) clearly favoured three of the four species which occurred there, but was probably the most important cause of the decline of the fourth. Habitat preferences and use were also different for this province than for most other provinces, with natural vegetation being preferred only by the Southern Black Korhaan (Table 1).

The Blue Crane was the species that selected for transformed habitats the most out of the six focal species; even in provinces where its population was declining it either selected for transformed habitats or showed no preference between natural and transformed habitats. Of the remaining species, only the two black korhaans did not select for transformed habitats in any province. Agricultural habitats that were most used by these species were mainly characterised by short vegetation or crop stubbles;

however crop fields were frequently used by Blue Cranes in most provinces, and by Blue Korhaans *Eupodotis caerulescens*, Denham's Bustards and Southern Black Korhaans in one province each. These crops may have been at any stage of growth, however (the height of the vegetation was not recorded), so these habitats may also have comprised low vegetation in most cases, as is likely considering these species' natural habitats.

Conservation implications of the study

The species that has emerged from this thesis as being the most in need of urgent conservation attention is the Southern Black Korhaan (Chapter 3). Its rate of decline in the Western Cape may have slowed since 2008, but this is based on only the last three years of the study period. Comparisons of SABAP1 and SABAP2 data showed that the population decreased in at least 80% of its range. It appears vulnerable to further environmental change, including climate change and ongoing transformation of natural habitats. Furthermore, if increased predation is part of the cause of the species' decline, this may constitute a substantial threat to the population in its diminished state. Classification of the species as Vulnerable is therefore recommended. A detailed study of the Southern Black Korhaan's biology, movements and habitat requirements is urgently required, to improve our knowledge of this species so that a detailed and effective conservation action plan can be drafted.

The Blue Crane, although increasing in numbers in its adopted agricultural habitat in the Fynbos biome, is vulnerable to land-use change throughout its range (Chapter 4). It is now so rare in parts of the Grassland biome, despite the similarity of some agricultural practices there to those in the Fynbos biome, that the CAR project was not able to index its abundance reliably in these areas. It appears to be holding its own in the grassy parts of the Nama Karoo biome, and may be expanding its range into more arid parts of this biome and into the Succulent Karoo biome, but this expansion is probably also dependent on anthropogenic alteration of the landscape, especially through the creation of small farm dams. It is recommended that the Blue Crane's current classification as Vulnerable remain unchanged.

The Denham's Bustard population probably declined overall, although the portion covered by the CAR project appeared to have increased slightly or remained stable (Chapter 5). As well as being vulnerable to habitat destruction and changes in farming practices, the species is also under threat from powerline collisions. As such it is recommended that its current status of Vulnerable remains unchanged, and that the status of this subspecies be taken into consideration when reassessing the species as a whole for the IUCN Red List. A detailed study of this subspecies' biology, movements, habitat use and susceptibility to powerline collisions is recommended, to inform future conservation action.

Populations of the Blue Korhaan, Karoo Korhaan and Northern Black Korhaan *Afrotis afraoides* appeared overall to be stable or increasing slightly (Chapter 6). However, when interpreting these results, it is important to bear in mind that the population of the Blue Korhaan and possibly also the Northern Black Korhaan had already been greatly reduced from their original levels in some areas before the CAR project and SABAP1 commenced (Young et al. 2003). Thus although they might appear to be stable now, they are likely to be vulnerable to further land-cover change, particularly intensive farming, the establishment of vineyards, changes to the crops cultivated and further transformation of natural habitats. Afforestation, mining and human settlements represent complete habitat destruction for these birds; they are almost never recorded in these habitats (CAR project, unpubl. data). It is recommended that the Blue Korhaan remain classified as Near-Threatened because of these threats and its limited range, much of which is prime agricultural land. Further study of all three of these species is also required, to improve our understanding especially of their habitat use and requirements, so that appropriate recommendations can be made regarding land-use change within their ranges.

These six species make use of transformed land to varying degrees. The Southern and Northern Black Korhaans make the least use of these habitats, and the Blue Crane and Denham's Bustard have adapted to them, particularly in the Western Cape. It seems that, with the exception of the Southern Black Korhaan, anthropogenic transformation of the Fynbos biome has had positive consequences for the bird species covered in this thesis; Blue Cranes, Denham's Bustards and Karoo Korhaans all appear to have benefitted from it. Karoo Korhaans also appear to have benefitted from anthropogenic modification of the Nama Karoo biome. Many aspects of land management affect the birds that make use of transformed and modified habitats, however, and it is important that farmers continue to be made aware of these factors and how they affect large terrestrial birds. A booklet for farmers containing advice on how to protect wildlife, particularly large terrestrial birds (Harrison and Young 2010) recommends the following actions:

- maintain habitat diversity (a combination of grain cultivation, livestock farming and patches of natural vegetation appears to be the most beneficial);

- reduce poison use, and where it is necessary to use poison, do it responsibly;
- monitor powerlines and other potentially hazardous structures, and report related bird mortalities to the relevant authorities;
- conserve natural vegetation where it still exists;
- create and maintain corridors of natural vegetation between cultivated areas;
- conserve wetlands, rivers and floodplains in their natural state wherever possible;
- monitor and protect breeding and roosting sites;
- manage fire appropriately (use the lowest burning frequency appropriate to the vegetation type and position firebreaks so as to minimise disturbance to soil, flora and fauna);
- control domestic animals (especially minimise the number of pets on the farm and restrict their access to areas away from farm buildings, where birds are more likely to be);
- educate farm labourers about birds specifically and about environmental issues in general;
- work with other farmers in the area to create a conservancy or to work together on conservation issues.

Indicators

One of the original subsidiary aims of this thesis was to investigate the potential of large terrestrial birds to be used as indicators of the state of the ecosystems in which they occur. In the event, a formal statistical investigation of this potential was beyond the scope of the project, but a brief qualitative assessment follows.

In the Grassland and Nama Karoo biomes, bustards and cranes appear to be useful indicators of habitat quality and natural veld condition. Because they depend on a wide variety of food types and are at or near the top of the foodchain, they may not be useful for pinpointing specific problems, but are nevertheless good indicators of the overall diversity and health of ecosystems (e.g. Morrison and Bothma 1998, Donald et al. 2002, Gregory et al. 2004, Pereira and Cooper 2006, Greenwood 2007). However, the Karoo Korhaan is hypothesised to be an indicator of disturbed karoo vegetation, because it appears to benefit from this type of habitat transformation, and may have become more common because of the expansion of this habitat niche (Chapter 6).

However, it would seem that with the possible exception of the Southern Black Korhaan, large terrestrial birds are probably not useful indicators of veld condition in the Western Cape. Their general preference for agricultural landscapes rather than natural vegetation in this biome means that they cannot be used as indicators of healthy natural ecosystems in this area. They may, however, be useful indicators of the level of agro-chemical use, because of their susceptibility to poisoning by some types of agro-chemicals. These birds depend on a wide variety of food types, and therefore have the potential to be negatively affected by a wide range of poisons. Mass mortalities of Blue Cranes have been reported in several parts of the country, although most of these were in the Grassland biome (Allan 2005).

Irrespective of the finer details discussed above, the presence of bustards and cranes in an area must indicate that a certain minimum amount of biodiversity is surviving there, because these species all rely on a wide range of food types. Therefore it is likely that successful conservation efforts which focus on these birds will succeed in conserving a wide range of other organisms as well. Several authors have recommended the use of birds as indicators of environmental change (Chapter 1), and there may be potential to develop a useful indicator of environmental health based on the abundance and diversity of large terrestrial birds.

Habitat availability data

A serious limitation to the habitat use analyses presented in this thesis was the quality and resolution of habitat availability data available for the whole country. Ideally, CAR observers should collect detailed habitat availability data on every survey. This would make it possible to perform detailed habitat selection analyses and from these infer which types of transformed habitat are most beneficial or detrimental to large terrestrial birds. However, as previously noted (Chapter 3), this is unlikely to be possible because the additional time requirements for recording such information would be likely to deter observers from taking part. An alternative would be to institute a system whereby agricultural extension officers collect these data on an annual or biennial basis, for the entire area under their responsibility, georeferenced to allow GIS analysis.

In general there is a great need for improved land-use data for the entire country. The NLC1994 and NLC2000 maps had a wide range of land-cover categories but were not entirely accurate (SANBI 2009), and the land-cover categories were not particularly useful for the analyses presented here (Chapter 1). The NLC2009 map has substantially fewer habitat categories and is therefore of more limited use overall. It was also created in a different format to the two previous NLC maps (they are in vector format while the NLC2009 is a raster), which presented substantial challenges when attempting to use all three maps for any analysis, and for using the NLC2009 map in conjunction with any CAR GIS files, which are all in vector format.

A more detailed, conservation-oriented map or set of GIS layers, in vector format, would be ideal. These layers should give some indication of protected areas and of the state of modified land, i.e. natural vegetation which is used for livestock grazing (e.g. heavily overgrazed vs. moderately grazed or heavily impacted vs. moderately impacted). An indication of the dominant crop types in different regions would be useful, as well as some information about the rotational systems used and the seasonality of crop cultivation, because all of these factors have a profound effect on the indigenous biota that are able to survive in those transformed habitats.

Coverage of bustards

Some areas that are important for bustards were not well covered by the CAR project or by SABAP2 as of early 2012, and this hampered our ability to accurately assess the status of the populations thus affected. In order to identify the most important areas for this group as a whole, we use a method employed by Underhill et al. (1998) to examine the diversity of a group of species over a large area using bird atlas data.

The method involved calculating a modified version of the Shannon-Weiner diversity index, group diversity (H_G), for each grid cell as follows

where G was the number of species in the group and q_i was the proportion of the number of checklists reporting species i to the total number of records of species within the group (Underhill et al. 1998). If only one species was present in the grid cell, $H_G = 0$. If no species were present, H_G was arbitrarily set equal to –1, so that these two situations could be distinguished. High diversity of the group, comprising both high species richness and large reporting rates, were reflected by large values of H_G.

This diversity index was calculated for SABAP1 data (Figure 1) and SABAP2 data submitted up until 8 February 2012 (Figure 2). Grid cells with an H_G value of –1 were left blank, and the remaining H_G values were divided into six quantiles for display purposes, so that, as far as possible, one-sixth of the grid cells were shaded in each colour (see section on derived reporting rate maps in Chapter 1). However, with the SABAP2 data, the majority of grid cells had only one species present and were therefore tied; all of these grid cells were assigned to the lowest quantile, and the remainder were assigned to the highest two quantiles.

During the SABAP1 study period (1987–1992), diversity of bustards was largest in the western half of the Eastern Cape, the eastern half to two-thirds of the Northern Cape, the north-western extreme of the North West, the north-eastern corner of the Western Cape and the far south of the Free State (Figure 1). This region corresponds approximately with the Nama Karoo biome, the Grassland–Nama Karoo ecotone and the drier western extremes of the Savanna biome (Figure 2 in Chapter 1). Other areas of high diversity were the area around the KwaZulu-Natal–Mpumalanga border and central Mpumalanga, the Kruger National Park (the strip of land along the northern half of the Mozambique border) and the Overberg region of the Western Cape. The conspicuousness of the Kruger National Park on this map indicates that although bustards may in general not be well conserved by protected areas, several species had a stronghold in this large game reserve.

Notable regions of low bustard diversity were the areas south and south-east of Lesotho and the area centring on south-eastern North West and including extreme north-western Free State and much of Gauteng. The former includes areas of high human population densities, large areas of degraded land and extensive sugar cane cultivation (Figure 5b in Chapter 1). The latter is the "breadbasket" of the country and is intensively cultivated. This map therefore provides support to the hypothesis that bustard species had already declined substantially as a result of anthropogenic land transformation by the time of the SABAP1 initiative in the late 1980s. Indeed, all except two of the species accounts for the bustards in the SABAP1 atlas, under the section "Historical distribution and conservation" consider the species to have decreased in range (Allan 1997).

The SABAP2 map (Figure 2) highlights the fact that by February 2012, there was a lack of fieldwork coverage of some of the most important areas for bustards, particularly in the Nama Karoo biome. It is critical that coverage in this region be improved, as soon as possible, to enable more meaningful analyses of the status of species whose ranges are centred there, and to enable range-change comparisons to be made. Figure 2 also provides further confirmation that bustard populations in KwaZulu-Natal and Mpumalanga decreased between the early 1990s and the late 2000s; coverage in these provinces was extensive by February 2012, but relatively few pentads had even one bustard species recorded.

These maps highlight how desirable it would be for the CAR project to expand its coverage farther into the Nama Karoo, and into the dry western Savanna in the north-east of the Northern Cape. However, for reasons discussed previously (Chapter 1), expanding the CAR project thus is unlikely to be possible in the foreseeable future. Areas such as the Kruger National Park are not ideal for a project such as CAR, because of the semi-closed to closed canopy Savanna woodland that characterises much of the park and therefore poor general visibility. In addition, disembarking from vehicles within game reserves is not permitted except at designated places, so the full CAR protocol could not be used there.

The findings in Chapter 2 show that some species are more reliably counted than others by a project such as CAR, and the difference depends on several characteristics of the species. These characteristics are mostly related to behaviour, but also to a degree to abundance. The main behaviour-related characteristics are flocking, the extent of nomadism or range of daily movements, and calling or display behaviour. Species which tend to occur singly or in small groups, are sedentary and make themselves obvious by conspicuous displays are the most reliably counted (e.g. Northern Black Korhaan), while species that form large flocks which move a relatively large distance each day, such as the Helmeted Guineafowl, are not reliably counted. In general, less abundant species are less reliably counted than more abundant ones, but this effect is secondary to behaviour, such that the Southern Black Korhaan, which is sedentary and calls fairly frequently, is more reliably counted than the Secretarybird, which is similarly scarce but moves large distances every day.

However, these analyses were based in all cases on just one route in a precinct. The more thoroughly an area is covered, i.e. the greater the distance of road covered in one area, the more reliably most species will be counted, especially if they tend to range over large areas, because the chances of detecting them on one of the routes will be higher if there are more routes, and if the density of routes is greater.

Species such as the partially nomadic Ludwig's Bustard, however, may never be reliably indexed by the CAR project, no matter how well its range is covered; it may be that it ranges too widely and erratically to be reliably censused by driving a set of fixed routes, unless coverage of the entire range were possible. This species has recently been classified on the IUCN Red List as Endangered, primarily because of the threat of powerline collisions. It is therefore highly desirable that a monitoring system more suited to this species be established as soon as possible.

At regular intervals, possibly once every five years, the national population indices developed here should be recalculated. As discussed in Chapter 4, the weights incorporating reporting rates should be adjusted to include SABAP2 data when coverage is almost complete. The choice of weights used should then be re-evaluated. Including these data in the weights is likely to have a large effect on indices in cases where species' abundance levels have changed to a great extent, e.g. the Blue Crane and the Southern Black Korhaan. This is yet another reason to improve SABAP2 coverage as rapidly as possible.

Other large terrestrial bird species

It was hoped that it would be possible to include analyses of the CAR data for Ludwig's Bustards *Neotis ludwigii*, Wattled Cranes *Bugeranus carunculatus* and Grey Crowned Cranes *Balearica regulorum* and Secretarybirds *Sagittarius serpentarius* in this thesis. However, it soon became apparent that extracting meaningful information from the data on these species would require some other method of population trend analysis than the one developed here. This was because the data were too sparse to enable any useful conclusions to be drawn using the present method. It is recommended, therefore, that alternative analysis methods for rarer and/or more nomadic species be investigated.

Of concern is the fact that the Blue Crane population was so poorly monitored in the KwaZulu-Natal precincts, relative to the information provided by the annual aerial surveys (Smith et al. 2010). This may be the case for the other crane species as well, and if so this suggests that the CAR project protocol is not suited to monitoring cranes in this province. This may be partly because the terrain is generally more undulating than much of the terrain in the west of the country, which affects visibility. However, it is likely to be mostly because the numbers of cranes are too low to be adequately monitored by a method that relies on sampling a fixed proportion of the population. An additional complication is these species are often in groups, which, as has been shown for the Blue Crane in the Overberg (Chapters 2 and 4), can decrease the reliability of surveys, and the Grey Crowned and especially Wattled Cranes are also more closely associated with wetlands than Blue Cranes, and therefore more patchily distributed.

Other species which are monitored by the CAR project and to which these methods of data analysis could be applied include all those present in large enough numbers and exhibiting the appropriate behaviour to ensure that the CAR totals are sufficiently reliable (Chapter 2). These are likely to include the Spur-winged Goose *Plectropterus gambensis*, Black-headed Heron *Ardea melanocephala*, White Stork *Ciconia ciconia*, Grey Crowned Crane (if coverage of its range improves), and possibly others, although caution would have to be exercised when interpreting results based on sightings of large flocks, as would be the case some of the time with some of these species. If other species were to be surveyed in a similar way, this type of data analysis could potentially be used for species such as crows and the common small raptors, and large raptors that occur in sufficient numbers, such as Jackal Buzzards *Buteo rufofuscus*, Long-crested Eagles *Lophaetus occipitalis*, Pale Chanting Goshawks *Melierax canorus*, Steppe Buzzards *Buteo buteo* and Yellow-billed Kites *Milvus migrans parasites*.

Concluding remarks

Bustards and cranes are enigmatic and charismatic birds which are affected by anthropogenic land transformation in a range of different ways. They are an important part of our natural heritage, and it is possible that they play important roles in the functioning of the ecosystems in which they live (e.g. the Karoo Korhaan may assist the recovery of disturbed areas by spreading seeds of coloniser plant species to those areas, Boobyer 1989). The cranes have already been shown to be effective foci for conservation efforts, and there is potential for a similar role for bustards. Improving our knowledge and understanding of these poorly known birds would add substantially to the likelihood of success of any conservation endeavours that were developed. Continuing the long-term monitoring projects discussed here, therefore, and expanding their coverage where possible, are imperative. More in-depth examination of the characteristics of the data they produce, building on the work presented in Chapter 2, would also be highly valuable. Furthermore, it is recommended that alternative monitoring projects and/or data analysis techniques more suited to monitoring trends in rarer species be developed urgently in order to inform species management and recovery plans.

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Table 1: Summary of population trend and habitat use results, by province. Trend rows give the overall trend suggested by CAR data analysis and SABAP comparison maps combined. Transformed / natural rows give the overall habitat preference; neutral indicates no clear preference was shown. Habitat most used rows show the habitats in which most CAR sightings were made overall, in approximate descending order of numbers of sightings.

		Blue Crane	Blue Korhaan	Denham's Bustard	Karoo Korhaan	N Black Korhaan	S Black Korhaan
Eastern Cape	Trend	stable	stable	increasing (SW) / stable (central & NE)	stable	stable	decreasing / stable
	Transformed / natural	transformed / neutral	transformed / neutral	transformed	natural	natural / neutral	natural
	Habitat most used	veld / stubble / pasture	veld / pasture / crops	veld / pasture / fallow	veld	veld	veld
Free State	Trend	increasing (SW) / stable or decreasing (central & NE)	stable	stable	decreasing	increasing	
	Transformed / natural	transformed / natural (S Free State summer only)	natural	natural	natural / neutral	natural	
	Habitat most used	veld / pasture / stubble / crops / bare	veld / stubble	veld	veld	veld	
Gauteng	Trend	decreasing	stable			increasing	
	Transformed / natural	neutral	data deficient			natural / neutral	
	Habitat most used	veld / crops / bare	data deficient			veld / burnt / pasture	
KwaZulu-Natal	Trend	decreasing	decreasing	decreasing			
	Transformed / natural	transformed / neutral	data deficient	neutral			
	Habitat most used	veld / stubble / crops / pasture	data deficient	veld / stubble / pasture			
Limpopo	Trend	decreasing		stable		decreasing	
	Transformed / natural	no data		no data		no data	
	Habitat most used	no data		no data		no data	
Mpuma-langa	Trend	decreasing	decreasing	decreasing		stable	
	Transformed / natural	transformed / neutral	natural / neutral	natural / neutral		no data	
	Habitat most used	veld / stubble / crops	veld / stubble	veld / stubble / bare		no data	
Northern Cape	Trend	stable	stable		data deficient	data deficient	decreasing / stable
	Transformed / natural	transformed	transformed		neutral	natural	no data
	Habitat most used	veld / pasture / crops	veld		veld	veld	no data
North West	Trend	decreasing				stable / data deficient	
	Transformed / natural	no data				no data	
	Habitat most used	no data				no data	
Western Cape	Trend	strongly increasing		increasing	stable		strongly decreasing
	Transformed / natural	transformed		transformed	transformed / neutral		natural
	Habitat most used	stubble / pasture / fallow / crops		pasture / stubble / fallow / crops	fallow / stubble / pasture / veld		veld / pasture / crops / stubble

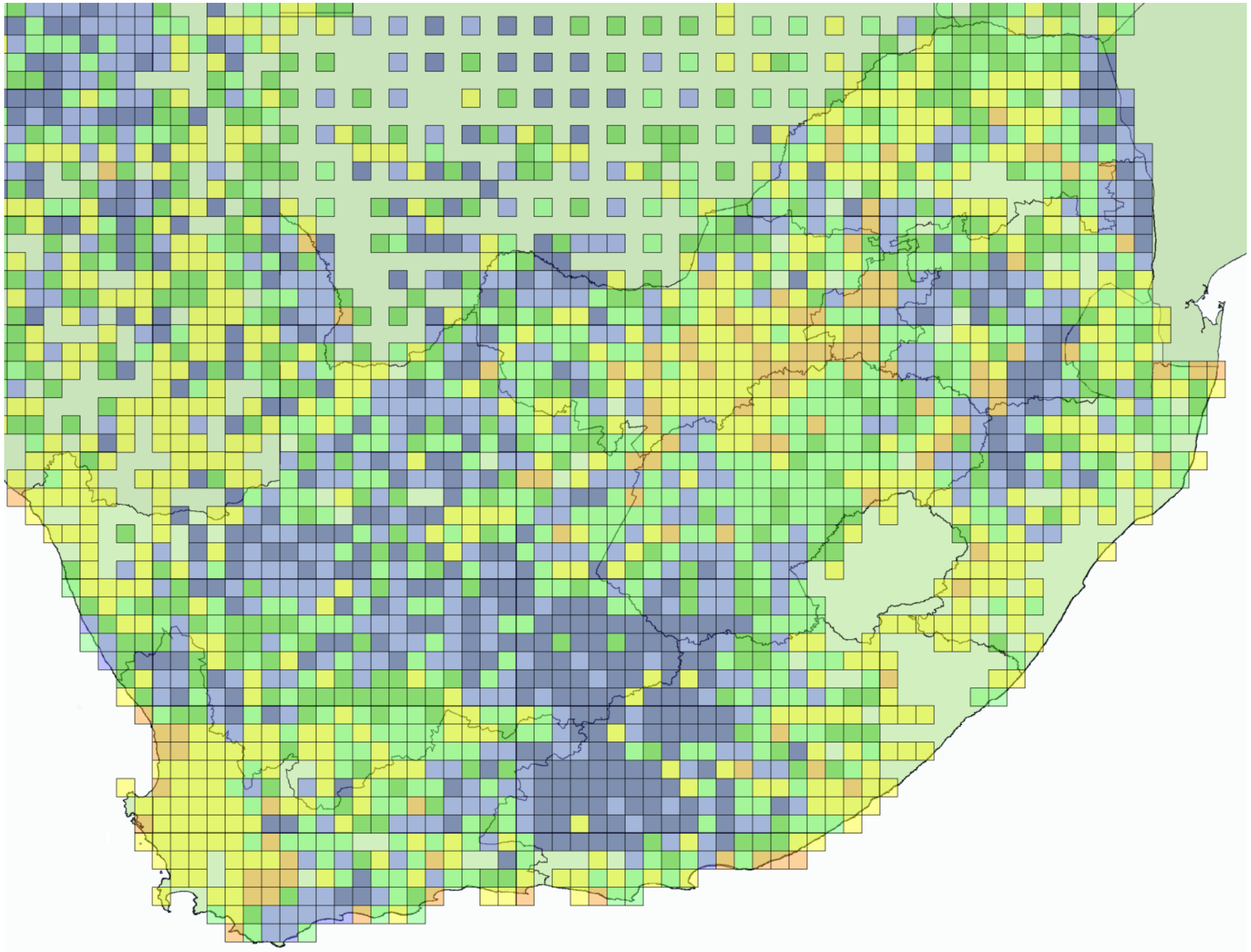

Figure 1: The diversity of the 10 species of bustards and korhaans (Otididae) occurring in South Africa based on data from the first Southern African Bird Atlas Project (SABAP1). Grid cells are quarter-degree grid cells (QDGCs; 15' × 15'). QDGCs are colour-coded according to a diversity index of the group (see text) divided into six quantiles. QDGCs shaded yellow had one species of bustard recorded, those shaded green had intermediate levels of diversity, and those shaded dark blue had the largest diversity.

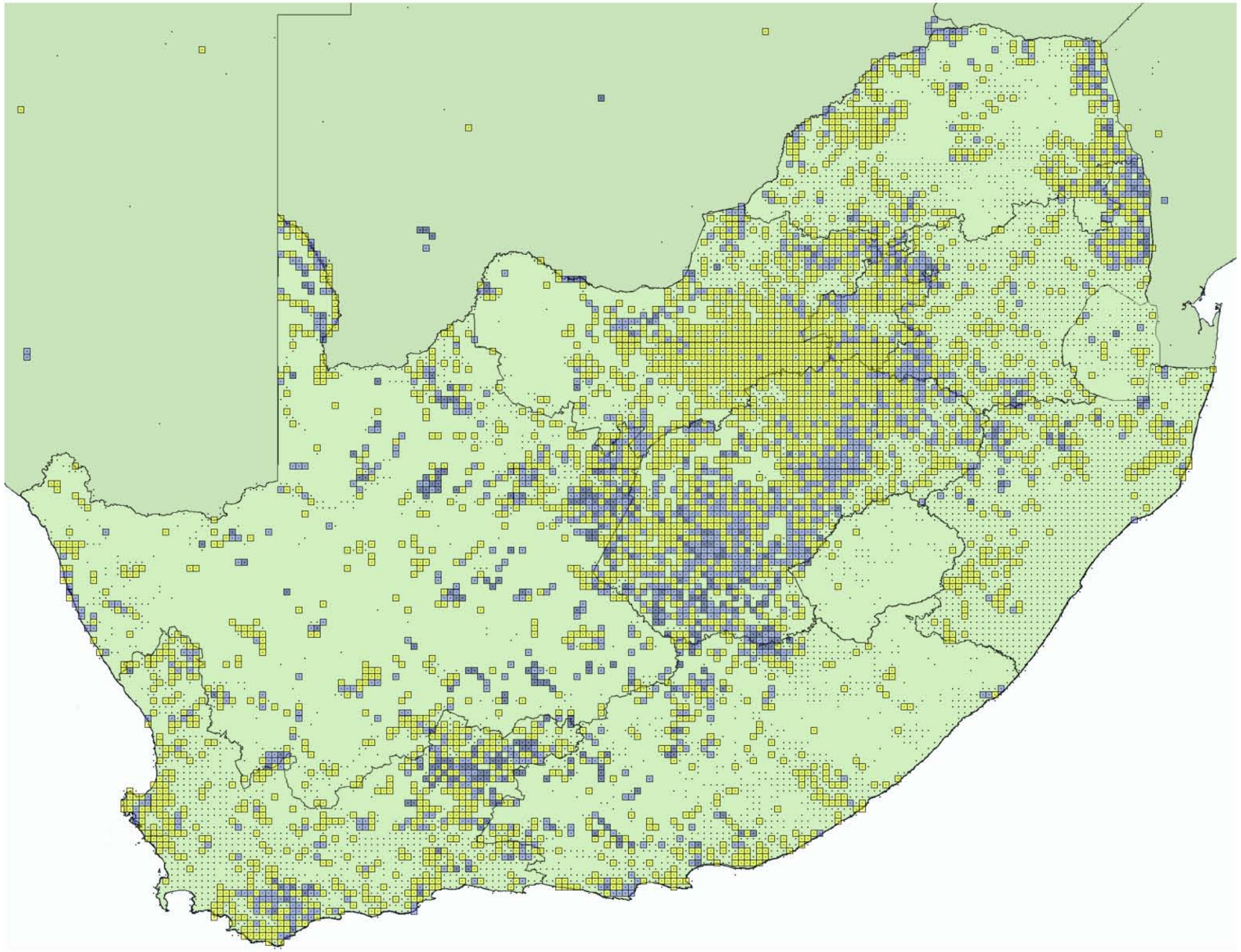

Figure 2: The diversity of the 10 species of bustards and korhaans (Otididae) occurring in South Africa based on data from the second Southern African Bird Atlas Project (SABAP2) submitted up until 10 February 2012. Grid cells are pentads (5' × 5'). Pentads are colour-coded as for Figure 1, except that those for which there are SABAP2 data but in which no bustards had been recorded are marked with a dot.

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