Geographic Range Dynamics of South Africa's Bird Species

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Thesis presented for the Degree of Master of Science in Zoology,
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South Africa

January 2014

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Plagiarism declaration

I know the meaning of plagiarism and declare that all of the work in this thesis, save for that which is properly acknowledged, is my own.

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Abstract

A key issue in species conservation is a knowledge of the geographic ranges of species, and how these are changing through time. For birds there is a special opportunity to undertake studies of range changes, making use of the data collected by the First and Second Southern African Bird Atlas Projects (SABAP1 and SABAP2), which are separated in time by about two decades.

In this thesis, I first describe the strengths and the weaknesses of the databases collected by these two citizen science projects, and therefore discuss the limitations placed on the analyses. We then undertake two sets of analyses, one focused on species, and one focused on areas.

I show that, across all species, the Family to which the species belongs is an explanatory variable which explains approximately 45% of range expansion or contraction of a species. Diet and mass are also significant explanatory variables. For the analyses by areas, we demonstrate that the general encroachment of shrubs and trees in the savanna biome appears to have had a profound impact on the occurrence and abundance of a large suit of bird species, with the small insectivores and frugivores showing the largest increases.

Acknowledgements

Firstly, I would like to give a huge thank you to my supervisor Les Underhill as well as Res Altwegg for all their help and support. Thank you so much for helping me through all the ups and downs of this MSc.

Thank you to the Animal Demography Unit for being such a great place to learn and grow! I am very proud to be part of the ADU family. And definitely a special thank you to Michael Brooks and Rene Navarro, you guys are amazing, thanks for all the help with programming, data tools and reporting rate maps. And a special mention to Sue Kuyper, you are the heart of the ADU.

Thank you to the National Research Foundation (NRF) and the Applied Centre for Climate and Earth Systems Science (ACCESS) for funding my MSc. And big thank you to the South African National Biodiversity Institute (SANBI) for all their guidance and support.

A big thanks to my two best friends, Milly Malan and Elsa Bussière, for keeping me sane and making me laugh. I love you girls so much!

And then last, but not least, a massive thank you to my parents and sister, Nadea, you have always supported me and I love you so much! Thank you for always being there for me.

Acronyms

ADU	Animal Demography Unit
CBC	Christmas Bird Count
QDGC	Quarter Degree Grid Cell
SABAP	Southern African Bird Atlas Project

Contents

CHAPTER 1

Introduction: Geographic range dynamics of South Africa's birds

Understanding why birds' geographical ranges are changing

The observation that organisms are changing their geographic ranges in apparent response both to recent land-use change and anthropogenic climate change has led to a renewed interest in the mechanisms that limit species' ranges and how the field of macroecology can contribute to a better understanding of this issue (Saether et al. 2007, Gaston 2009, Sexton et al. 2009). For example, in the northern hemisphere, species are extending their ranges pole-wards as predicted under the observed patterns of climate change for that hemisphere (Parmesan and Yohe 2003, Root et al. 2003, Parmesan 2006). There is little comparable evidence from the southern hemisphere or from tropical latitudes in general (Rosenzweig et al. 2007).

The ranges of numerous southern African birds changed noticeably during the 20th century. There are four striking examples of birds that have expanded their ranges: Hadeda Ibis *Bostrychia hagedash* (Macdonald et al. 1986, Underhill and Hockey 1988, Anderson 1997), Yellow-billed Oxpecker *Buphagus africanus* (Stutterheim and Brooke 1981), South African Cliff Swallow *Hirundo spilodera* (Rowan 1963) and Southern Grey-headed Sparrow *Passer diffusus* (Ward et al. 2004, Craig et al. 1987). The Hadeda Ibis has greatly expanded its range, especially towards the west. The south-western limit of the historical range was at Knysna, South Africa, until about 1950. The Hadeda Ibis's southern African range increased from 530 900 km^2 in 1910 to 1 323 300 km^2 in 1985 (Anderson 1997). The major expansions were into the Fynbos biome of the Western Cape, the Karoo, the grasslands of the Eastern Cape, the Free State and the highveld areas of Gauteng (Anderson 1997). Reasons for expansion include a reduction in persecution by humans, an increase of alien trees in areas that were treeless in the past, an increase in the number of artificial water points (dams and reservoirs), and very importantly the increase in availability of perennially moist feeding grounds as a result of irrigation in dry areas (Anderson 1997). The Yellow-billed Oxpecker expanded its range both naturally; colonizing the Kruger National Park around 1979 when buffalo (*Syncerus caffer*) herds moved in from Zimbabwe, carrying oxpeckers with them as well as artificially, through translocations to areas like Matobo National Park in Zimbabwe (Mundy 1997). The Yellow-billed Oxpecker populations are thus well on their way to recovery, after near decimation early in the 20th century, aided by translocations and natural expansion. Outside protected areas, the changeover to oxpecker-compatible 'green label' dips on cattle farms have further aided the range expansion process (Mundy 1997). The South African Cliff Swallow expanded its range because of its ability to nest on man-made structures (Earlé 1997). This species has a very large range, with Extent of Occurrence >20,000 km^2 (BirdLife International 2013b). Their range in South Africa has expanded significantly into the Eastern Cape and Northern Cape Province due to construction of artificial breeding sites like bridges (Hockey et al. 2005). The Southern Grey-headed Sparrow has adapted well to human-modified habitats and has dramatically increased its range, especially in the Western Cape. In Lesotho, it has spread into the mountains along the rivers (Craig 1997b). The Southern Grey-headed Sparrow's range expansion can be attributed to its wide use of different habitat types which results primarily from commensalism with humans and its use of alien tree plantations near human habitation (Craig 1997b).

Examples of birds' ranges that have contracted include the Blue Swallow *Hirundo atrocaerulea* (Allan 1988), Red-billed Oxpecker *Buphagus erythrorhynchus* (Bezuidenhout and Stutterheim 1980), Burchell's Courser *Cursorius rufus* (Hockey et al. 2005), Eurasian Bittern *Botaurus stellaris* (Dean 2005), and many raptors (Boshoff et al. 1983). The Blue Swallow is restricted to montane grassland with high rainfall areas where suitable nesting sites are available. The loss of suitable breeding and feeding habitat is the most important reason for the Blue Swallow's range contraction (Allan and Earlé 1997). In the past, the Red-billed Oxpecker was vulnerable to arsenic-based cattle dips which poisoned and killed both the ticks and the oxpeckers that fed on the ticks on the dipped cattle (Mundy 1997). With the use of oxpecker-compatible 'green label' cattle dips the Red-billed Oxpecker is starting to recover though (Mundy 1997). The Burchell's Courser avoids woodland habitat of any kind. Its abundance has declined in the southern part of its range. The reasons behind the Burchell's Courser's decline are not well understood (Maclean and Herremans 1997). The Eurasian Bittern's range contraction can be attributed to wetland degradation (Allan 1997).

Hockey and Midgley (2009) documented the chronology and habitat use of 18 bird species that colonized the Western Cape Province of South Africa after the late 1940s and found that there were 18 species with largely altered ranges. Their study incorporated a period of almost four decades of observed regional warming in the Western Cape (Hockey and Midgley 2009). Observations of these colonization events concurred with a 'climate change' explanation, assuming extrapolation of Northern Hemisphere results and simplistic application of theory (Hockey and Midgley 2009). However, on individual inspection, all bar one may be more parsimoniously explained by direct anthropogenic changes to the landscape than by the indirect effects of climate change (Hockey and Midgley 2009). Indeed, no a priori predictions relating to climate change, such as colonizers being small and/or originating in nearby arid shrublands, were upheld (Hockey and Midgley 2009).

This suggests that observed climate changes have not yet been sufficient to trigger extensive shifts in the ranges of indigenous birds in this region, or that a priori assumptions are incorrect (Hockey and Midgley 2009). Either way, Hockey and Midgley's study highlights the danger of naïve attribution of range changes to climate change, even if those range changes accord with the predictions of climate-change models. Nonetheless, studies of human-induced changes in fauna communities, such as that of the Cape Peninsula, and the dynamics of these observed range shifts, may provide insight into processes likely to take place should climate change trigger significant poleward movement by Southern Hemisphere birds (Hockey and Midgley 2009).

Birds, in common with other terrestrial organisms, are predicted to exhibit one of two general responses to land-use/climatic change: they may adapt to the changed conditions without changing location, or they may show a spatial response, adjusting their geographical distribution in response to the changing environment (Huntley et al. 2006). As far as biological indicators go, birds are an extremely valuable taxonomic group. Birds are bio-indicators of the state of the environment. In general, areas that have high bird diversity are also rich in other forms of biodiversity (BirdLife South Africa 2013b). The presence or absence of birds can give you a good idea of the health of the environment. Birds are sensitive to environmental changes and this makes them a good taxonomic group for the purpose of studying geographic range dynamics (Koskimies 1989, Furness and Greenwood 1993). Citizen science, through projects like bird atlasing, and the popular hobby of birdwatching has helped to draw attention to bird conservation and research. Citizen science is the participation in scientific research by members of the general public. An example of birdwatching and citizen science coming together is the Christmas Bird Count (CBC) in North America. The CBC is a census count of birds in the Western Hemisphere, done by volunteer birdwatchers (Bird Studies Canada 2013). It takes place annually in the early Northern-hemisphere winter and is administered by the National Audubon Society. The purpose of the CBC is to provide population data of birds for use in science, especially conservation biology (Bird Studies Canada 2013).

Climate and landscape-level changes can cause changes in the distributions of bird species (Hockey 2003). These changes can detrimentally affect bird populations that are vulnerable to environmental changes. South Africa is a useful case study to examine the changes in species ranges that have occurred, because it is a region susceptible to changing atmospheric conditions; it has a wide diversity of habitats/biomes and substantial anthropogenic land-use changes have taken place (Harrison and Underhill 1997, Hockey 2003).

It has been recognized that vegetation and habitat patterns influence the distribution and abundance of birds. This has been recorded, both in Africa (Chapin 1923, Moreau 1966, Harrison et al. 1997) and elsewhere (Cody 1985). Vegetation patterns, specifically plant community type and vegetative structure, are determined by a wide variety of climatic and soil related factors, of which the former are the more significant (Rutherford and Westfall 1994). The predictability and seasonality of total rainfall, and atmospheric temperature determine moisture availability and are the most important climatic factors (Walter 1979). Analyses relating bird distribution patterns to vegetation types, both in Africa and elsewhere, have proved to be very insightful (Winterbottom 1978, Cody 1985). The reasons behind these enlightening analyses is due to vegetation type and structure revealing a lot of information about climatic and non-climatic factors, such as latitude, altitude, topography, atmospheric circulation and the influence of ocean currents (Chapin 1923, Tyson 1986, Gentilli 1992). Examples of some African, particularly southern African, studies that have successfully related selected bird distribution patterns to vegetation types include Benson and Irwin (1966), Moreau (1966), Winterbottom (1968, 1972), Tarboton (1980), Hockey et al. (1988), Dean and Hockey (1989), Osborne and Tigar (1992), Bruderer and Bruderer (1993), Parker (1996, 1999a).

The study area – South Africa

South Africa (Figure 1.1) occupies the southern tip of Africa and covers an area of 1 220 813 km^2. South Africa's coastline stretches for more than 2500 km from the west coast where it borders the deserts of Namibia on the Atlantic Ocean, southwards around the southern tip of Africa and then north, along the Indian Ocean, to the border with Mozambique (Rutherford and Westfall 1994). South Africa has a wide diversity of habitats (Harrison and Underhill 1997, Sinclair et al. 2002). There are nine major terrestrial biomes within South Africa: Forest, Savanna, Grassland, Fynbos, Nama Karoo, Succulent Karoo, Albany Thicket, Indian Ocean Coastal Belt and Desert (Rutherford and Westfall 1994).

The landscape of South Africa is dominated by a high plateau in the interior, which is surrounded by a narrow strip of coastal lowlands (Low and Rebelo 1996). South Africa differs from the rest of Africa, because of the perimeter of its inland plateau that rises abruptly to form a series of mountain ranges before dropping to sea level (Low and Rebelo 1996). These mountains, known as the Great Escarpment, vary between 2000 m and 3300 m in elevation. The coastline does not vary much and there are few natural harbors (Low and Rebelo 1996). Every one of the major land features—the mountain ranges, the inland plateau, and the coastal lowlands—shows a wide range of variation in vegetation, topography and climate.

Because of the great variety of habitats, South Africa has a high bird diversity with the bird list standing at 853 species of which about 50 are endemic or near-endemic (BirdLife South Africa 2013a). The major centre of endemism lies in the arid western regions, the Karoo and desert regions (Sinclair et al. 2002).

Changes in habitat and land-use in South Africa

One of the major influences on bird distributions is the changes that have occurred on the landscape throughout time due to human activity. Landscapes, such as that of the Succulent Karoo, are not just a product of their evolutionary and climatic histories, but also a product of human intervention over the last few centuries. Bush encroachment, which is the increase of the woody component within savanna or grassland at the expense of the herbaceous component, has increased dramatically throughout the Savanna Biome of South Africa (O'Connor and Chamane 2012). One approach to recording the long-term environmental changes and impacts of humans on habitats is through the use of historical photographs (Hoffman and Rohde 2011). This requires the observer to re-locate and re-photograph the historical image from as close to the original position as possible and then interpret the changes visible in the matched images in terms of the environmental and cultural influences on the landscape (Hoffman and Rohde 2011).

The data – Southern African Bird Atlas Projects

This project revolves around two databases, collected at intervals of roughly two decades – The Southern African Bird Atlas Projects. Together, these two atlas projects have collected over 11 million bird distribution records. The database is widely used by environmental consultants (for example, to locate electricity transmission lines), conservationists (planning conservation strategies), research scientists (especially macro-ecologists and bio-geographers) and birders (ecotourism materials) (Harrison et al. 2008).

Data collected from the first Southern African Bird Atlas Project (SABAP1: 1987–1991) and the second Southern African Bird Atlas Project (SABAP2: 2007-present) have shown that many of the bird species in South Africa have undergone range changes in the past 20–30 years. The data from the two bird atlas projects offer a unique opportunity to study the structure and dynamics of species' ranges.

The objective of the bird atlas projects, as with most biological atlases, is to provide some insight on a changing biogeographical scene (Harrison et al. 1997). Bird atlasing is a form of biodiversity and biological research as well as citizen science, and it should be viewed as an active and continual monitoring exercise rather than a once-off, single "snapshot" survey. The New Atlas of Breeding Birds in Britain and Ireland showed the importance of monitoring changes in species distributions (Sharrock 1976, Gibbons et al. 1993). In that atlas, the ever-changing nature of species geographic ranges and population densities, even over a short period of 20 years, was clearly proven (Harrison et al. 1997).

The first Southern African Bird Atlas Project (SABAP1) started in 1986 and officially collected data from 1987 to 1991. Citizen scientists (bird atlasers) gathered data on bird distributions from six southern African countries: Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe (Harrison 1992, Harrison et al. 2008). From this project the book, The Atlas of Southern African Birds, was published in 1997 (Harrison et al. 2008). The goal of SABAP1 was to provide a better understanding, and a complete coverage map, of bird distributions in southern Africa (Harrison and Underhill 1997). For most ornithological purposes, southern Africa is frequently defined to include the six countries mentioned, plus southern and central Mozambique, the part of Africa south of the Kunene and Zambezi Rivers (e.g. Hockey et al. 2005). Atlas fieldwork in Mozambique was not possible during the SABAP1 era because of civil war, but was achieved subsequently (Parker 1999b, 2005).

Bird atlas data from before 1986 and after 1991 was incorporated into the SABAP1 database to improve overall coverage (Harrison and Underhill 1997). SABAP1 provided a ‘snapshot’ of the distribution and relative abundance of birds in southern Africa and was a great example of a project which improved the public understanding of science, and which played a key role in science education (Harebottle et al. 2007). The Second Southern African Bird Atlas Project (SABAP2) built on the results of SABAP1 in order to produce an improved atlas and contribute in a greater way to biodiversity conservation (Harebottle et al. 2007).

For SABAP1, the Quarter-Degree Grid Cell (QDGC) was the geographical sampling unit. QDGCs are grid cells that cover 15 minutes of latitude by 15 minutes of longitude (15’ × 15’) and correspond to the areas shown on standard 1:50 000 topographical maps of South Africa (Harebottle et al. 2007). The SABAP2 sampling unit is called the “pentad”; these cover 5 minutes of latitude by 5 minutes of longitude (5’ × 5’). Each pentad is approximately 8.0 km × 7.6 km. The north to south length remains the same everywhere on the Earth, but the east to west length gets narrower as move southwards because of the spherical shape of the

Earth (Harebottle et al. 2007). Luckily, within southern Africa this change is not large (Harebottle et al. 2007). There are nine pentads per QDGC. The 15×15-minute grid gave an excellent broad brush picture of bird distributions. Because the pentads are nested within QDGC, the data for pentads can be combined into QDGC format, which can then be compared with SABAP1 data to detect any large-scale changes in bird distribution. SABAP2 was initially confined to South Africa, Lesotho and Swaziland, and this limitation constrains the area of comparison for this project to these three countries. There are 17 444 pentads covering South Africa, Lesotho and Swaziland, compared to the 2002 QDGCs for SABAP1.

Figure 1.2 shows four Quarter-Degree Grid Cells (15'×15'). Each of the nine blocks in each QDGC represents a pentad. The pentad code is the coordinates at the top-left hand (north-west) corner of the pentad grid cell (shown by the circles). For example: Pentad code for grid A is 2920_2935 (because 29° 20'S, 29° 35'E are coordinates for the northwestern corner of the pentad). Similarly the pentad code for grid B is 2935_2945 (29° 35'S, 29° 45'E).

At the start of SABAP2, the project had three main objectives (Harebottle et al. 2007):

- To measure the impact of environmental change on southern African birds through a scientifically rigorous and repeatable platform that uses standardised data collection on bird distribution and abundance;

- To provide a basis for increasing public participation in biodiversity data collection, and public awareness of birds, through large-scale mobilization of citizen scientists;

- To provide information that can be used to determine changes in the distribution and abundance of birds since SABAP1.

This MSc project aims to make a start on doing the analyses relevant to the first and third of these objectives mentioned above. It is in fact the first systematic attempt to determine whether SABAP2 has achieved these two goals.

The difficulties with comparisons between SABAP1 and SABAP2

It needs to be recognized that the problems of making comparisons between SABAP1 and SABAP2 are proving more difficult than envisaged at the start of SABAP2. To a large extent, the problems in the comparison between SABAP1 and SABAP2 relate to the change in scale at which data is collected, from the quarter degree grid cell (15-minute grid) to the pentad (5-minute grid) so that there are nine pentads per quarter degree grid cell. Up to now, all analyses have simply lumped the nine pentad lists together, and treated them as equivalent to the lists from SABAP1 for the quarter degree grid cell. There are multiple, but inter-related problems with this approach. Three papers have been published in the online journal, Ornithological Observations, comparing data between the first and second Southern Africa Bird Atlas Projects (McKenzie 2011, De Swardt 2012, Carter 2012). Here follows a discussion about the various problems with comparisons between the two bird atlas projects:

In SABAP1 there was no incentive to undertake complete coverage of a QDGC. In the editorial of the newsletter to SABAP1 participants that was produced four months after the start of the project there is a section of questions about participation and answers (Harrison 1988). One question asked was, "Is it worth filling in a card for a square which I only see a small part of?” and the answer was "Yes! Your card, as incomplete as it may be, will help build up a complete picture together with other cards from that square” (Harrison 1987). In other words, checklists (“cards”) were welcomed even if they covered only a small part of the area of a QDGC (“square”). In reality, the “complete picture” for the QDGC did not necessarily emerge from this process, and much of the SABAP1 data for a grid cell tended to come from a subset of good birding spots within the grid cell, or the most accessible parts of it and not from the area as a whole (L.G. Underhill pers. comm.). In contrast, the primary fieldwork instructions for SABAP2 is "Spend at least two hours recording as many different species in the pentad by visiting all (or as many different) habitats as possible" (http://sabap2.adu.org.za/howto.php#4). Thus there was a fundamental shift in fieldwork protocol between the two projects.

Road access within QDGCs is not always evenly spread throughout the QDGC. For example, the 3322DC quarter degree grid cell which is located in the area near the town of Knysna in the Western Cape Province. In this particular QDGC there is road access in the south (which includes coastal and forest habitat) and in the north (which is Little Karoo semi-arid shrubland habitat), and the Outeniqua Mountain range across the middle of the QDGC. There was no road access across the QDGC, and to get from the north to the south involved a detour over the Outeniqua Pass which lies in the adjoining QDGC. Any list for the QDGC would either have been made to the south or the north of the mountain range and this creates bias in the data collected for that QDGC.

There was no measure of observer effort in the SABAP1 data, and it is known that some lists were made from cars travelling through QDGCs at 120 km/hour (30 km of road through a QDGC would therefore take 15 minutes to traverse). In addition, lists were made covering a full month, but these frequently related to a single locality within the QDGC. However, it is known that the overwhelming majority of SABAP1 lists were made during the period of a single day, and most represented several hours (1–6 hours) of intensive birding. Not having a measure of observer effort does create problems in data comparisons, however, it seems that most SABAP1 checklists are in fact compatible with SABAP2 checklists in terms of time spent doing fieldwork.

One of the ways to compare the two bird atlas projects with one another is to look at a direct comparison of the number of species recorded in QDGCs between SABAP1 and SABAP2. One can also compare the reporting rates of species between the two atlases, but it is imperative to take into account the influence that the differences in protocols, especially the time span (time spent birding) and the differently sized areas (nine pentads to one QDGC) has on the collected bird checklists.

The news item of 21 March 2013 on the SABAP2 website regarding the African Marsh-Harrier *Circus ranivorus* indicates that this species has a lower reporting rate in QDGC 3218CC for SABAP2 as compared to SABAP1. The reporting rate is the proportion of checklists on which a species is recorded, out of the total number of checklists submitted for that specific QDGC. This might be true, but there could be a diluting effect of cards submitted for pentads within a QDGC where a habitat-specific species cannot be found anywhere else within the QDGC except for a very specific site.

Example 1: African Marsh-Harrier in QDGC 3218CC near Velddrif, Western Cape Province

According to SABAP1, this QDGC had a reporting rate of 19% for the species, whereas SABAP2 indicates 13.3%. The bulk of the recordings in SABAP2 come from pentad 3245_1810 (47 records, with a 22.5% reporting rate). This pentad within the QDGC was most likely the main hub where observations in SABAP1 for African Marsh Harrier, and other species, came from. According to observers that have been to this area before SABAP1 started, the reed beds in specific parts of this pentad near Velddrif have increased in density and have become almost inaccessible for humans, and as a consequence has in fact created more suitable habitat for the African Marsh-Harrier. There are SABAP2 records for African Marsh-Harrier in two other pentads within this QDGC, but these areas are peripheral habitat. The other six pentads within the QDGC have no records of African Marsh-Harrier and therefore play diluting roles in the comparisons between SABAP1 and SABAP2 reporting rates. It is probably not unrealistic to use the 22.5% reporting rate for African Marsh-Harrier in pentad 3245_1810 as the QDGC reporting rate for

SABAP2, since this pentad is the area where atlasers in SABAP1 would have observed it.

Example 2: African Black Oystercatcher *Haematopus moquini* in QDGC 3218CB

For QDGC 3218CB the reporting rate for the African Black Oystercatcher was 68% in SABAP1. For SABAP2 the reporting rate has dropped considerably to 40.5%. This decreased reporting rate, however, can also be due to dilution of the data. There are 34 records of African Black Oystercatcher for SABAP2 in this QDGC and they are all from pentad 3235_1815 (Rocher Pan Nature Reserve, Western Cape Province). Within this pentad the African Black Oystercatcher has a 73.9% reporting rate. Observations for this species in SABAP1 were most likely made in this pentad and therefore one could argue that the 73.9% reporting rate should be used for making comparisons between SABAP1 and SABAP2.

Example 3: Pienaarsrivier QDGC 2528AB

This QDGC is located about 50 km north of Pretoria. During SABAP1, 146 checklists were submitted for this QDGC. For SABAP2, when combining the nine pentads in 2528AB, 173 checklists were submitted (Retief 2013). Fifty four species recorded in SABAP1 have not been recorded in SABAP2. Of the 54 species, only two, Rock Kestrel *Falco rupicolus* and Common Quail *Coturnix coturnix*, have a SABAP1 reporting rate of over 10%. Twenty three species have been recorded during SABAP2 but not during SABAP1 (Retief 2013). Reporting rates have increased for Red-billed Oxpecker *Buphagus erythrorhynchus* and Yellow Canary *Crithagra flaviventris.* The range expansion of Red-billed Oxpecker is attributed in part to the phasing out of harmful livestock acaracides in favour of products that are not harmful to this species. This change therefore reflects a genuine change in the abundance of this species (Retief 2013). Yellow Canary has also been reported regularly by birders in northern Gauteng and southern parts of Limpopo. Natal Spurfowl *Pternistis natalensis* shows an increased reporting rate of 36.0%, the second highest after Common Myna *Acridotheres tristis*. It was recorded 73 times in the QDGC in only three pentads 2505_2815, 2510_2815 and 2520_2825.

In pentad 2510_2815 this species was recorded 56 times, 76.7% of all records! If a number of these records are removed then this species might even show a decline in reporting rate.

From these three examples it is clear that we need to be cautious when comparing reporting rates between the two atlases, but it is unclear whether there is a systematic direction of bias in reporting rates between SABAP1 and SABAP2. The direction of the "bias" effect on reporting rates in a particular grid cell between the two projects is unpredictable. For some QDGCs reporting rate would have gone up and for others it would have gone down. If, in spite of this, there is a dominance of changes in a single direction (such as for the Southern Masked Weaver *Ploceus velatus*, which has a range-change map where most QDGCs show increased reporting rates for SABAP2), then the comparisons are still meaningful.

Suppose the biological truth is that the species has increased everywhere, then, as a consequence of the biases resulting from the differences between SABAP1 and SABAP2 protocols and sampling variation, we will not have increased reporting rates in every grid cell, so in fact the number of increases will be underestimated. Or, suppose that a species has increased in two thirds of the QDGC, then the biasing processes will shrink the number of observed increases closer towards one half. It is the second scenario which is the critical one. The biological truth is likely, on average, to be more extreme than what we observe.

From the time of SABAP1 to SABAP2 there has been a substantial improvement in bird identification skills. The availability of improved bird books, the internet, and digital photography have all helped to improve observers' identification skills. The book "Chamberlain's LBJs: The definitive guide to Southern Africa's *Little Brown Jobs*" (Peacock 2012) represents the quality of identification material which became available during the SABAP2 project. This book focuses on 235 species of "Little

Brown Jobs" (or LBJs as they are known), a term that birders assign to any smallish, brownish and featureless bird that defies identification. Through its wealth of accurate illustrations, and comprehensive text, the book helps beginners and experienced birders alike to confidently identify LBJs. Part of the increase in the reporting rates for cisticolas (as discussed in Chapter 2) might be attributable to improved skills in bird identification.

Because SABAP1 checklists covered a QDGC and a SABAP2 checklist a pentad, one-ninth of the area of a QDGC, it would be predicted that SABAP1 checklists would be longer than SABAP2 checklists. In fact the average lists lengths are 49.7 and 53.0 species respectively; the opposite direction to what was predicted, but nevertheless remarkably similar (calculated from data presented by Harrison and Underhill 1997, and from the SABAP2 website). This point is revisited in Chapter 2, where for a subset of the data analysed more intensely, the checklist lengths between projects were even closer. What this also suggests is that the total amount of observer effort per checklist was broadly similar in both projects. It is even possible that the part of the QDGC visited by the average SABAP1 observer was roughly a pentad-sized subset of the QDGC.

Reporting rates provide a way of extracting quantitative information from presence/absence data, like that provided by the bird atlas projects. The observers did not count the actual number of birds they observed, but they recorded the presence of identified species on checklists (Harrison and Underhill 1997). The reporting rate is the proportion of checklists on which a species is recorded. If a species was recorded on 10% of checklists then it has a reporting rate equal to 10% for the specific grid cell. Differences in reporting rate between different geographical areas, and times of year, may be interpreted as pointing to changes in abundance or density of birds (Harrison and Underhill 1997). However, reporting rates are not proportional to birds per hectare (density). Reporting rates provide an index which varies with changes in bird density (Harrison and Underhill 1997).

Reporting rate can be seen as a measure of conspicuousness (how easily a bird is seen or noticed) of a species, which may roughly be defined as the likelihood that the average observer, with an average amount of effort invested in searching for a species, records a species (Harrison and Underhill 1997). Many factors influence reporting rate, only one of which is relative abundance. The sources of bias in reporting rates can be categorized into species, geographic, observer and arithmetic effects (Harrison and Underhill 1997):

(1) Species effects: Some bird species are more easily observed than others. With equal abundance, a conspicuous species will be recorded on checklists more frequently than species that are of a secretive nature. For some species, conspicuousness varies between seasons, because of changes in plumage or behaviour, with no change in abundance. Bright breeding plumage makes birds conspicuous and easy to identify while drab nonbreeding plumages do the opposite.

(2) Geographic effects: Some areas are more easily accessible than others. Species that are habitat specific will only be encountered if the observer goes to this specific habitat. Some grid cells have good networks of roads allowing access to all parts; others have few roads making access to some important habitats difficult.

(3) Observer effects: Certain species are easily identified by observers and are therefore recorded more frequently than those species that are difficult to identify. The level of observer skill and experience can affect the reporting rate.

(4) Arithmetic effects: the number of checklists collected for a grid cell can influence the reporting rate. If there is one checklist, the only possible values for the reporting rate are 0% and 100%. If there are two checklists, values of 0%, 50% and 100% are possible. If there are 100 checklists, the reporting rate can have any integer value from 0% to 100%. For this reason, observers were

urged to revisit grid cells as often as possible, and collect as many checklists as possible.

With all these biases, do reporting rates have any value at all? Its usefulness might be less for certain species (e.g. rare or illusive species), and in certain field conditions, than for others, but it has demonstrated its value in numerous ways (Harrison and Underhill 1997).

Reporting rates have proven to be highly valuable when it comes to describing the phenology of migratory species. The reporting rates show a clear rise and fall with the arrival and departure of migrants (Harrison and Underhill 1997). Reporting rates vary over geographical space and this corresponds with what is predicted for species' ranges. For example, reporting rates are usually highest in the core of a species' distribution and lower towards the periphery (Harrison and Underhill 1997). This is consistent with studies on the structure of distributions (Brown 1984). Likewise, reporting rates for different vegetation types frequently follow the patterns of the known habitat preferences of species and this gives assurance that they are meaningful (Harrison and Underhill 1997). Studies on bird densities have used reporting rates from the SABAP database and related them to independent quantitative measures of species' densities, and found a consistent positive correlation; it has been demonstrated with compelling evidence that reporting rates increase in a continuous manner with increasing population density (Du Plessis 1989, Bruderer and Bruderer 1993, Allan 1994, Robertson et al. 1995).

Harrison and Navarro (1994) acknowledged that reporting rates are "crude measures" of relative abundance, yet successfully used them to make an important contribution to the debate about appropriate sizes for protected areas. They demonstrated for example, that there was a positive relationship between body mass and the size of the protected area, with the larger species tending to have larger reporting rates in the larger protected areas. Based on reporting rates, Harrison and Navarro (1994) were able to draw conclusions such as: "This suggests that an area of the order of 2500 ha may be an effective minimum for many small- to medium-sized woodland species (up to 400 g body mass), while considerably larger areas are needed for species of large body size.”

In spite of the difficulties in interpretation of changes in reporting rates between SABAP1 and SABAP2, especially at the individual grid cell level, it is likely that if the SABAP2 results for a species shows decreased reporting rates (or complete absence) over large parts of its range, or vice versa, then this may be interpreted as an indication of genuine range change (Underhill et al. 2013).

Because average checklist lengths are comparable, the overall average of all reporting rates, across all species and all grid cells, is similar for both SABAP1 and SABAP2 (Underhill et al. 2013). Suppose a species has unchanged abundance between projects. Then, because of both sampling errors and comparison issues, roughly equal percentages of grid cells can be anticipated to show increases or decreases in reporting rates. Suppose a species has decreased in abundance in every grid cell between projects. Then sampling errors and comparison issues will result in some grid cells showing increased reporting rates, but the majority will show decreased reporting rates. Suppose a species has in reality decreased in abundance in 75% of grid cells and increased in 25%. Then sampling errors and comparison issues will result in observed decreases in, say, 65% of grid cells and increases in 35%. In other words, it is likely that, for species that have actually decreased, the observed percentage of grid cells with reporting rates that show decreases is likely to be underestimated. And similarly, for species that have increased, the observed percentage of grid cells with reporting rates that show increases is likely to be underestimated. In both cases, the observed change is likely to be “shrunk” towards 50%. Comparisons are thus more likely to be conservative, than to exaggerate increases or decreases.

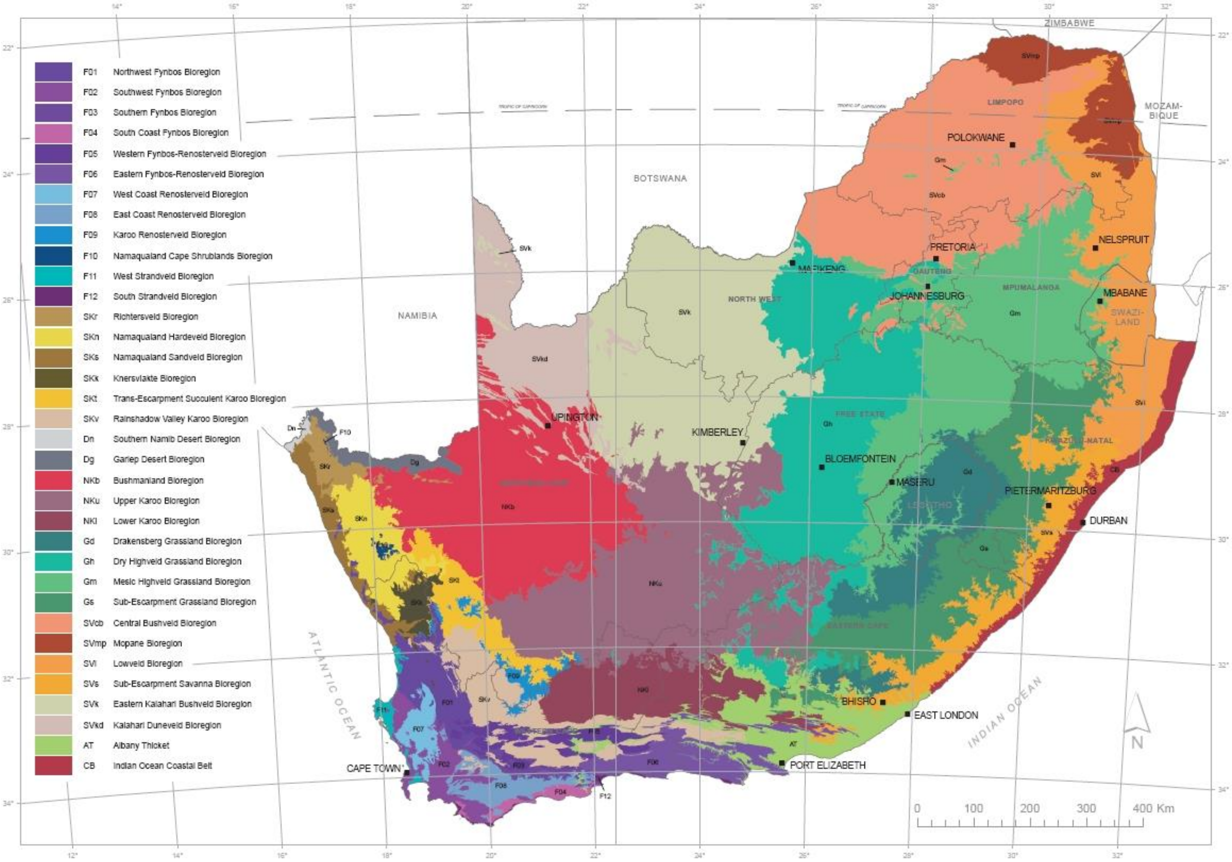

Figure 1.1 Vegetation map of South Africa, Lesotho and Swaziland – Mucina and Rutherford (2006)

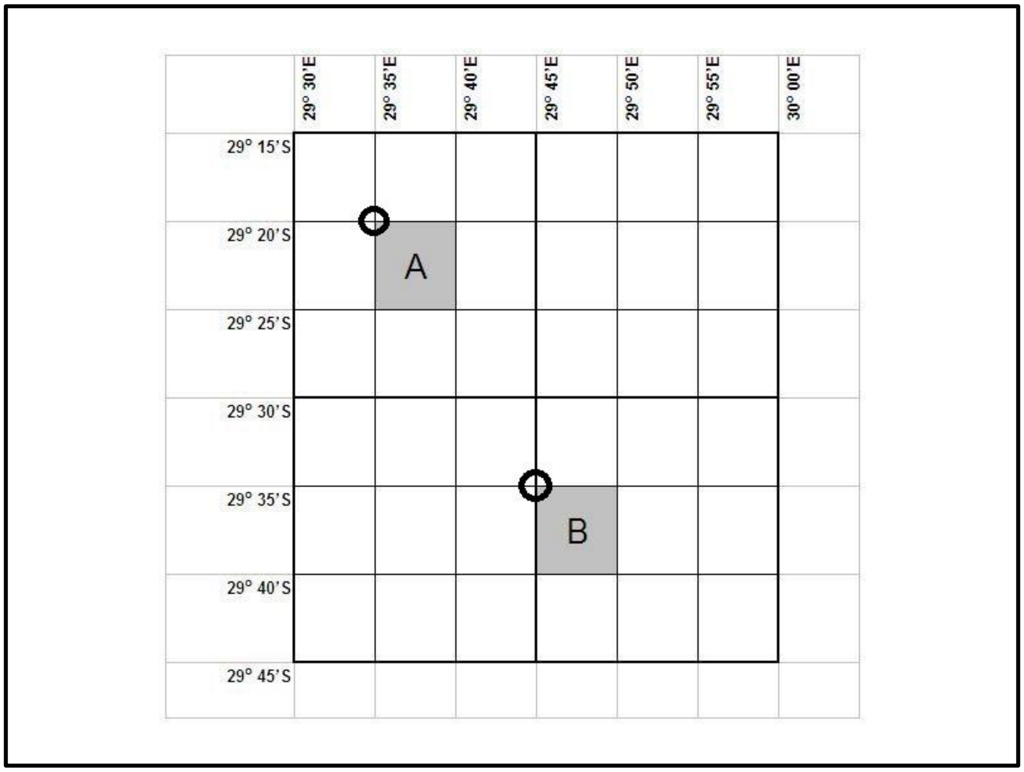

Figure1.2 Four QDGCs with nine Pentads each. Pentads are named by the coordinates of the northwest corner of the pentad. Therefore A is pentad 2920_2935 and B is pentad 2935_2945

CHAPTER 2

Changes in bird distributions between SABAP1 and SABAP2 in relation to family

Introduction

Characterizing species distributions is a fundamental objective in ecology (Andrewartha and Birch 1974, McIntire and Fajardo 2009) and biodiversity conservation (Wiens and Graham 2005). Tracking changes in species distributions can give information about species habitat use. Many questions relating to wildlife conservation, protection and management can only be answered by first answering questions about distribution (Gibbons et al. 2007).

Accurate distribution maps and population size estimates are essential for effective conservation of species (Underhill and Gibbons 2002). We cannot conserve species properly if we do not understand their geographic range dynamics, therefore the conservation status of a species centers around three questions: 'Where are they?', 'How many are there?' and 'What is their trend?' (Underhill and Gibbons 2002). The Southern African Bird Atlas Projects strive to answer the question 'Where are they?' and provide data on spatial patterns of species distributions and how these are changing. Bird atlases are important tools in conservation and have become a popular form of citizen science (Greenwood 2007).

Birds are useful indicators of biodiversity. Monitoring birds through atlas projects can provide information on the distribution of biological diversity and it can signal changes occurring in ecosystems.

Southern Africa is one of many regions in the world in which two consecutive atlas projects provide data to describe the range dynamics of species. The British Bird Atlas started as a pilot project to map the distribution of 100 species in the West Midlands in 1950 and was followed up in 1952 by a survey using the 25 km × 25 km National Grid squares that mapped the distribution of 30 species in Britain and Ireland (Norris 1960). The Atlas of Breeding Birds in Britain and Ireland was organised by the British Trust for Ornithology (BTO) and Irish Wildbird Conservancy (IWC) (Sharrock 1976). It was estimated that 10 000–15 000 observers contributed, resulting in dot-distribution maps with the size of the dot representing levels of breeding evidence (possible, probable and confirmed). It was a step forward in knowledge of the distribution of British and Irish birds. The third atlas to be carried out was The New Atlas of Breeding Birds in Britain and Ireland (Gibbons et al. 1993). Records from 42 736 tetrads (2 km × 2 km grid cells) in 3 858 10-km squares were gathered. This atlas used comparable methods to the 1968–1972 atlas, allowing change in range of species over the intervening period to be mapped (Sharrock 1976, Gibbons et al. 1993).

Determining the underlying causes of the changes in distribution documented by the range change maps was complicated, but some general themes emerged, and one of these was the influence of breeding season habitat (Gibbons et al. 1993). Species were divided into six habitat classes: coastal, farmland, lowland wetland, urban, upland and woodland. For all habitat types except farmland, the number of species with increasing or decreasing ranges was similar (Gibbons et al. 1993). Out of 174 non-farmland species, 85 increased and 89 decreased their range. For farmland species, however, 24 out of 28 species (86%) decreased (Gibbons et al. 1993). These results confirmed those of the Common Birds Census (CBC), which has documented long-term declines in populations of many farmland birds (Gibbons et al. 1993). There is strong circumstantial evidence that changes in farming practices in the mid-1970s were responsible for the changes in bird population and distribution (Sharrock 1976, Gibbons et al. 1993).

The initial Atlas of Australian Birds ran between 1977 and 1981 and collected data at a spatial resolution of one-degree grid cells (Barrett et al. 2003). The new Atlas has been running since 1998 and has collected over six million bird records. Across Australia, and its external Territories, a total of 772 bird species was reported, 595 of which breed in Australia. Excluding oceanic islands, analysis of patterns was possible for 422 species. Of these, 201 (48%) showed no change between atlas projects, 64 (15%) were recorded less frequently during the second project, and 157 (37%) were recorded more frequently (Olsen et al. 2003). The State of Australia's Birds 2003 (SOAB) is the first in a series of reports summarizing the fortunes of Australia's birds (Barrett et al. 2003). It presents population trends and changes for Australian birds over various time spans—some extending from the 1960s—leading up to the present. These reports, that are generated every five years, feed into the Australian Government's State of Environment reporting as an indicator of national environmental health (Olsen et al. 2003).

While temporal comparisons between bird atlases can reveal a lot of valuable information, they require caution if, for example, the protocols/fieldwork methods or the levels of coverage differ (Underhill and Gibbons 2002). Increased coverage could convey the impression that a species' range changed when in fact it remained stable (Underhill and Gibbons 2002). To overcome this, some measure of observer effort can be incorporated into the analysis (e.g. hours spent birding).

In this chapter, and the next, I discuss the range changes that have occurred between the First and Second Southern African Bird Atlas Projects (SABAP1 and SABAP2). In this chapter the focus is on changes which are related to family. For selected families I consider the results in more detail, at the species level. Eight families were chosen for this in depth analysis. The basis of choice was a family where there were consistent range increases by a large proportion of the species within the family, a family with a diversity of range expansions and contractions, and a family with consistent range decreases. A more general comparison, using life history parameters of each species as explanatory variables of range changes, is undertaken in Chapter 3.

Methods

Data sources

The study area was the SABAP2 region, consisting of South Africa, Lesotho and Swaziland. SABAP1 also included Namibia, Botswana and Zimbabwe; the data for these countries were excluded from this analysis. The bird distribution and reporting rate, i.e. the proportion of checklists for a grid cell that reported a given species, were extracted from the databases of SABAP1 and SABAP2 for 2007 quarter degree grid cells (QDGCs) in the study area.

The data for this chapter were downloaded from the databases of the two atlas projects in the following format which generated one record per species for each QDGC in which it occurred: the code for the QDGC, the unique species code, the number of SABAP1 checklists for that grid cell, the number of these which recorded the species, and likewise for SABAP2. The SABAP1 data had been collected at the scale of the QDGC, whereas the SABAP2 data were collected on the pentad (5min x 5 min) scale and the data for the nine pentads within the QDGC were pooled. (There are nine pentads for most QDGCs, except at coastal QDGCs and those along the borders of the atlas area with Namibia, Botswana, Zimbabwe and Mozambique – see Chapter 1 for details of SABAP1 and SABAP2.) This downloaded data file contained 358 784 lines, one for each species recorded in each grid cell in either SABAP1 or SABAP2. There were records for 790 species, from 93 families. From this file all records for grid cells with fewer than four checklists for both SABAP1

and SABAP2 were removed, resulting in a file with 309 248 records, with data from 1 399 QDGCs. The analysis was thus confined to QDGCs with four or more checklists for both bird atlas projects. Species that had been subject to taxonomic splits between SABAP1 and SABAP2 were omitted from the analysis.
The SABAP1 data for these species were collected as a single taxon, and splitting the data into two taxa is not possible.

Statistical analysis

Reporting rates for each species in each of the QDGCs were computed. There is a discussion of the difficulties in making comparisons using the SABAP1 and SABAP2 reporting rates in Chapter 1. The total number of QDGCs in which each species was recorded in either SABAP1 or SABAP2 was determined, and called the total range, denoted N_i. We considered only species which had a range of 100 or more QDGCs. The reporting rates for each species in both SABAP1 and SABAP2 were calculated, where the reporting rate is defined as the ratio of checklists recording the species divided by the total number of checklists for the QDGC. I calculated the number of QDGCs in which the reporting rate had increased between SABAP1 and SABAP2, and denoted this u_i.

I modelled u_i as a generalized linear model with a binomial distribution, $u_i \sim B(N_i,p_i)$. I modelled p_i as a function of explanatory variables through the logit transformation. In this chapter, only a single explanatory variable was considered, and that was family, modelled as a “factor” variable, with one level per family.

Estimated values of p_i close to 0.5 suggest that the species has as many grid cells in which the reporting rate has increased as cells in which it has decreased or not changed. The inference is that the status of the species did not change between SABAP1 and SABAP2. If the modelled value of p_i is much larger than one-half, then the species had many more grid cells in which the reporting rate increased than cells in which it had decreased. The inference is that the species had become more frequently reported in SABAP2 than in SABAP1, and the most likely explanation is that the species had increased in range and/or abundance. On the other hand, if the modelled value of p_i is much smaller than one-half, then the species had many more grid cells in which the reporting rate decreased than cells in which it had increased. The inference is that the species had become less frequently reported in SABAP2 than in SABAP1, and the most likely explanation is that the species had decreased in range and/or abundance.

Because the direction of the change in reporting rates in adjacent QDGCs is likely to be spatially auto-correlated, the assumption that each observation entering the generalized linear model is statistically independent is likely to be violated. The consequence is that results are likely to be more statistically significant than they ought to be. I attempted to gauge the magnitude of this problem in three ways.

(1) I subsampled the data in four ways, progressively creating larger and larger gaps between the QDGCs that were actually used in the analysis. Firstly, I removed alternative grid cells in a chessboard pattern, so that 50% of the grid cells were retained. In terms of the standard nomenclature for QDGCs, the cells with suffixes AA, AD, BA, BD, CA, CD, DA and DD were retained. Secondly, one QDGC per half degree grid cell was retained, thus using 25% of the data; the cells with suffices AA, BA, CA and DA were retained. Thirdly, two QDGCs per degree cell, those with suffixes AA and CA, were retained, 12.5% of the data. Finally, only one QDGC per degree cell was retained, so that 6.25% or 1/16th, of the data were used. Only the QDGCs with suffix AA were retained in each degree cell. The criteria for selecting species were adjusted correspondingly, from the original minimum range of 100 QDGCs to 50, 25, 12 and 6 grid cells in the four subsampled analyses, respectively. The generalized linear model described above was fitted to the subset of the data; the sample size is based on the number of species, which remained the same across models. The results obtained from the subsets are thus comparable with each other and the model based on all the data.

(2) The standard empirical variogram (Webster and Oliver 2007) is intended for use to detect spatial autocorrelation in continuous measurement data, so its application to a binary variable needs to be interpreted cautiously. The binary variable was whether the difference in reporting rates had increased or not for a species in a QDGC. I calculated the semi-variogram to a distance of three degrees at one-quarter degree intervals. I did this for a large number of species and report the results for a representative selection: Common Fiscal *Lanius collaris*, Cape Turtle Dove *Streptopelia capicola*, African Stonechat *Saxicola torquatus*, Southern Masked Weaver *Ploceus velatus*, Southern Ground Hornbill *Bucorvus leadbeateri* and Brown-hooded Kingfisher *Halcyon albiventris*. The variogram was calculated using the FVARIOGRAM directive of GenStat 15 (VSN International 2012).

(3) I tested whether the pattern of adjacent QDGCs was random, given the proportion of grid cells within the range at which the reporting rate had increased. I selected a systematic sample of pairs of grid cells from throughout the range of every species, and classified each pair of cells into three categories: both cells increased in reporting rates, one cell increased and the other cell decreased, and both cells decreased. Expected values in each category were determined from the overall proportion P of grid cells in which the reporting rate had decreased, based on the values of P^2, $2P(1-P)$ and $(1-P)^2$ multiplied by the size of the systematic sample. For the 514 species considered, I computed the numbers in categories of significance, using the chi-square distribution with two degrees of freedom. The systematic sample consisted of pairs of QDGCs from within the range of the species for which both grid cells had more than four checklists; using the standard notation for QDGCs in the region, the pairs had suffixes AA and AB, BC and BD, CA and CB and DC and DD.

Results

Summary statistics

Within the 1 399 QDGCs with four or more checklists for both projects, 514 species from 79 families had a range of 100 QDGCs or more and hence were included in these analyses. (276 species and 15 families which had been recorded in the database for the study area were excluded because they did not meet this range size criterion or had been subject to taxonomic splits between the two projects.) The total number of records for these species within the 1 399 QDGCs was 5.28 million for SABAP1 on 108 509 checklists and 4.16 million for SABAP2 on 82 918 checklists. The mean checklist length for SABAP1 was 48.6 species and for SABAP2 was 50.2 species. These are the mean checklist lengths for the 514 species in the 1 399 QDGCs with four or more checklists, and do not apply to the database as a whole. The overall mean reporting rate for these 514 species was 9.46% in SABAP1 and 9.77% in SABAP2.

The mean range size, across both SABAP1 and SABAP2, of these 514 species was 551 QDGCs, of the 1 399 being used in this analysis; the median was 467, and the lower and upper quartiles were 243 and 784 QDGCs respectively. The maximum range was 1394 out of 1 399 QDGCs, for the Cape Turtle Dove. In the entire study area, Cape Turtle Dove was recorded in 1 938 (96.6%) of the 2007 QDGCs (Figure 2.1). This "range-change" map, and that in Figure 2.2, is included to illustrate the nature of the data which underpin these analyses.

Of the 514 species, the mean number of QDGCs in which the reporting rates for species had increased was 265 (median 205, lower quartile 102 and upper quartile 380, range 22 to 996). The minimum was for the Southern Carmine Bee-eater *Merops nubicoides* which increased in reporting rate in 22 of the 131 QDGCs (16.8%) of the QDGCs in its range and either decreased or did not change in the remaining 109 QDGCs. The Southern Masked Weaver was the species which showed the largest number of QDGCs in which the reporting rate had increased; the value was 996 (71.2%) of the 1399 QDGCs in its range.

The mean percentage of QDGCs in which the 514 species had increased in reporting rate was 46.9% (median 47.6%, quartiles 36.4% and 56.4%). The smallest percentage increase was 13.8%, for the Southern Ground Hornbill, and therefore this species also has the largest decrease, namely in the remaining 86.2% of QDGCs. The largest percentage increase was 88.0%, for Mallard Duck *Anas platyrhynchos*, which increased at 147 out of 167 QDGCs.

Family as explanatory variable

The model which included only family as explanatory variable explained 46.6% of the deviance (Table 2.1). This model included 79 families with at least one species having a range of more than 100 QDGCs. The back-transformed probabilities of increasing reporting rates (i.e. the probability of a family's range having increased reporting rates) varied from 13.8% to 66.3% (Table 2.2). The Pycnonotidae (bulbuls, greenbuls, brownbuls, and nicators) family had the highest probability of increased reporting rates and the Bucorvidae family, of which the Southern Ground Hornbill *Bucorvus leadbeateri* is the only representative, family had the lowest. The mean probability of increased reporting rate for a family was 44.1% with the lower quartile at 36.2% and the upper quartile at 50.6%.

As anticipated, the subsampled models resulted in increasingly smaller percentages of deviance explained (Table 2.3). The percentage of deviance explained decreased from 46.5% with the complete data set to 42.4% when only one-eighth of the data was retained, i.e. two QDGCs per degree cell. When only a single QDGC per degree cell was retained, the analysis was based on 88 QDGCs, and the percentage deviance explained decreased to 34.9% (Table 2.3). In each case, the general pattern of the detailed results was similar to that of Table 2.2.

For most species, the magnitude of the value in the variogram at distance 0.25 degree was similar to that of the general variance, indicating no spatial autocorrelation (Table 2.4). The species which showed a degree of spatial autocorrelation were those which had large range expansions and increases in reporting rates over large areas (Red-billed Quelea *Quelea quelea*, Common Myna *Acridotheres tristis*).

Of the 514 species, the null hypothesis of random patterning between pairs of adjacent QDGCs was accepted at the 5% significance level for 384 (74.7%) species (Table 2.5).

The results of the eight families that I have chosen to discuss in more detail are reported in Tables 2.6–2.10. I have selected three of the families near the top of Table 2.2, a family which displays wide variability of change within the family, and four families at the bottom of Table 2.2. The Family Pycnonotidae showed the largest increase of all families in percentage of QDGCs showing an increase in reporting rate of 66.3% (Table 2.6). The mean increase in reporting rate for the Pycnonotidae was 68.1%, the lower quartile was 62.7%, and the upper quartile was 71.1% (Table 2.7). The Cisticolidae (cisticolas and African warblers) family has also increased over large parts of its range (Table 2.7). The mean probability of increased reporting rate in a cisticola species' range was 64.2%, the lower quartile was 59.4%, and the upper quartile was 69.9%. The Tawny-flanked Prinia *Prinia subflava* had the highest probability of increased reporting rates within its range at 75.6%. For the 22 species of weavers, the increase reporting rate percentages ranged between 40.6% and 80.8% (Table 2.8). Of the 10 species with increased reporting rate percentages greater than 60%, all except one, Southern Red Bishop *Euplectes oryx,* have habitat descriptions that specifically mention habitat types that are associated with bush thickening, such as thicket, thornveld, riverine vegetation and savanna (Table 2.8).

The mean probability of increased reporting rate in an accipiter species' range (Family Accipitridae) was 39.6%, the lower quartile was 31.6%, and the upper quartile was 47.1% (Table 2.9). The mean probability of increased reporting rate in a Ciconiidae species' range was 35.1%, the lower quartile was 19.7%, and the upper quartile was 45.6% (Table 2.10).

Discussion

Spatial autocorrelation

In this study, no direct comparison is made of reporting rates, or changes in reporting rates, between adjacent grid cells. It is therefore not clear that spatial autocorrelation is a serious consideration. The analysis was based on counts of numbers of grid cells in which a species had been recorded, and the number of these in which the reporting rate increased.

Spatial autocorrelation would result in a pattern in which increases or decreases in reporting rates of adjacent grid cells being likely to be in the same direction; Figures 2.1 and 2.2 it would be visually represented by adjacent grid cells tending to have the same colour. If spatial autocorrelation is present, it results in exaggerated levels of significance. If spatial correlation is overwhelming, it can result in spurious findings. This is thus an important topic to address.

If spatial autocorrelation at a distance of one quarter of a degree were large, but decreased fairly rapidly out to a distance of one degree then we would anticipate that there would be a substantial decrease in percentage deviance explained in each successive line in Table 2.3. However, Table 2.3 shows a gradual decrease in the percentage deviance explained and therefore its results can be interpreted in one of two ways. Either the spatially subsampled models demonstrate that spatial autocorrelation is a serious issue even when the sampling intensity is reduced to two QDGCs of the 16 in the degree cell, or that spatial autocorrelation is not a serious issue at all. The final line of Table 2.3 can be dismissed as an artifact, because reducing the database to a single QDGC per degree square results in an analysis based on only 88 of the original 1399 QDGCs and does not do the database justice. The results of Table 2.4 suggest that the second interpretation is more likely than the first. For almost all species examined, and a selection of these are shown in Table 2.4, had variograms in which the values at all lags were comparable with the general variance, suggesting that spatial autocorrelation was not a severe issue. One species which showed a marked degree of spatial autocorrelation was the Common Myna, with value 0.048 at lag 0.25 degrees compared with a general variance of 0.129; this is inevitable given that the reporting rate for this species is increasing almost everywhere. The general pattern is that for species which are increasing there was a tendency for a degree of spatial autocorrelation, but for species which were decreasing (such as the Southern Ground Hornbill) there was less of a tendency to find spatial autocorrelation (Table 2.4).

The entire topic of spatial autocorrelation in the bird atlas datasets needs further investigation, on a species-by-species basis. From this preliminary analysis, the conclusion is that, in the way that the analyses are performed here, some degree of autocorrelation is present in the data, at least for some species, and especially those that increased in reporting rates between the two atlas projects. However, it is unlikely that any of the general conclusions are invalid since the observed patterns were so clear.

Reporting rates

This analysis depends critically on the extent to which the simple dichotomy, reporting rates have either increased or decreased, reflects the true biological situation in relation to changes in abundance. There was a fuller discussion of this issue in Chapter 1, and key highlights in relation to this chapter are mentioned here. Harrison and Underhill (1997) pointed out four factors, besides abundance, which influence reporting rates, and which would impact the dichotomy on which this chapter is based.

(1) Arithmetic effects. If sample sizes, i.e. the numbers of checklists for SABAP1 and SABAP2, are small, straightforward sampling error results in the wrong decision. To reduce (but not eliminate) this influence, I only considered QDGCs with four or more checklists in both SABAP1 and SABAP2.

(2) Observer effects. Identification skills of the observers who were responsible for the checklists for an individual QDGC in SABAP1 and SABAP2 might have varied. Given that the projects were two decades apart, there are few observers who participated in both. No meaningful action can be taken to reduce this bias. However, the observer effect is certain to be both positive and negative, and with the large number of QDGCs is more likely to introduce noise than bias into the analyses.

(3) Species effects. Harrison and Underhill (1997) cautioned against making comparisons of reporting rates between species, because of the key role that conspicuousness plays in determining reporting rates. The reporting rate comparison I am making in this chapter is the one which is the least problematic of all; I am comparing reporting rates on a binary basis for the same species within a single QDGC.

(4) Geographic effects. Harrison and Underhill (1997) stated: "Geographic effects on reporting rates are caused by the way that geographical features influence the access of observers to the places where species occur." The change in geographical resolution from QDGCs in SABAP1 to pentads in SABAP2 is likely to be the most influential of the four factors listed by Harrison and Underhill (1997) on this analysis. This is discussed in detail in Chapter 1. The pentad system of SABAP2 has undoubtedly encouraged observers to visit the more inaccessible parts of QDGCs (because now the QDGC has been "broken down" into smaller parts, and all of them need to be surveyed separately), so that species which occur only there will have larger reporting rates for SABAP2 than for SABAP1. At the other extreme, consider a QDGC with a single wetland which falls into one pentad; this wetland would have been visited by most SABAP1 observers, but the species would be recorded in only one of the nine pentads in SABAP2, resulting in smaller reporting

rates in SABAP2 for the species that only occur at this wetland. There is no immediate solution for this problem, which will influence certain comparisons of SABAP1 and SABAP2 data, not only this one. A detailed scan of all 2007 QDGCs needs to be undertaken, in consultation with birders with local knowledge, and the proportion of problematic QDGCs estimated. A problematic QDGC would be defined as one in which the simple pooling of the data from the individual pentads which comprise the QDGC, as done in this analysis, is likely to induce a serious bias. Given that habitats over most of the study area, and especially the interior, are fairly uniform, it is unlikely that more than, say, 20%, of the QDGCs would be defined as problematic.

These comparisons also depend on the species. Shorebirds will always be problematic because they are unlikely to be seen in the pentads inland. The same applies to waterbirds that are restricted to wetlands. The more mobile or generalist species are less likely to be affected. What this means for my analysis is that the species that I have found to have undergone the most change in terms of geographic range, are not the ones that would be deemed most problematic.

Family as explanatory variable

At face value, it is remarkable that the single explanatory variable, family, plays such a large role in accounting for the proportion of grid cells showing increases in reporting rates between SABAP1 and SABAP2. No other variable which I have considered had comparable explanatory power (Chapter 3). What is also remarkable to note is the pattern among families, i.e. that the higher ranking families (in terms of probability of increased reporting rate) are all bush birds and the lower ranking families are all birds associated with open spaces. Most members in many bird families often have similar ecological requirements. For example, all the Cisticolidae are relatively small insectivores and share many characteristics; indeed, the family introduction to the Cisticolidae in the Handbook of the Birds of the World (Ryan et al. 2006) stated: "Foraging techniques vary little within the family, with most prey taken by picking or gleaning from leaves. The small size of these birds allows them to explore to the tips of slender branches, and they spend relatively little time in foraging on thicker branches and larger stems." Similarly, for breeding it is stated: "With a few exceptions, cisticolas are solitary, territorial breeders and probably monogamous. They typically have enclosed nests." These commonalities of ecological requirements occur in most bird families. In general, it is true that variation within families is far smaller than variation between families. In the light of this, it is perhaps not surprising that family is such a powerful explanatory variable in this context, accounting for almost half of the total variability in increases and decreases.

Instead of discussing the results for all 79 families superficially, I have chosen to select eight families, and consider these in more detail to try and tease out the reason why certain families, and certain species within the families, are doing better (in terms of numbers of grid cells showing increased reporting rates between the two bird atlas projects) than others. Clearly, this is a rich arena for further analysis.

The Families

In broad brush summary, the families that are doing the best (Pycnonotidae, Cisticolidae and Ploceidae), in terms of the range with increased reporting rates, seem to be those families that prefer treed/wooded habitats. In contrast, the families that are doing the worst (Bucorvidae, Scopidae, Ciconiidae, and Sagittariidae) are the families that are habitat specific and vulnerable to human-induced changes on the landscape, and also to human disturbance.

Pycnonotidae

The Pycnonotidae, which includes the bulbuls and nicators, is a family of small- to medium-sized passerine birds (Table 2.6, Figure 2.3). Most species in this family are sedentary with a few local migrants (Hockey et al. 2005). They mainly occur in forest or forest edge habitats, but also woodland and savanna (Hockey et al. 2005).

Their diet consists mainly of fruit and insects, supplemented by nectar and pollen. Members of this family breed solitarily and most are monogamous, but a few species are cooperative breeders, with helpers at the nest (Hockey et al. 2005, Table 2.6). Nests, usually deep cup nests, are built by the female. Chicks are altricial and fed by both adults. In southern Africa this family is represented by 10 species in five genera (Hockey et al. 2005). Six species had a range of 100 or more QDGCs in the study area (Table 2.6). The Family Pycnonotidae showed the largest increase of all families in percentage of QDGCs showing an increase in reporting rate (Table 2.2). The most likely explanation for the large increase in this family is an expansion of habitat suitable for these species, and an associated increase in food availability. It is striking that the predominant colours on the range-change maps of the species in the Pycnonotidae family are green and blue (Figure 2.3), demonstrating increased reporting rates (green), and some range expansion (blue), in the two decades between the two bird atlas projects. The broadly increased reporting rates within the SABAP1 range suggest that the habitat must have become more suitable for these species, along with increased food availability. Most species in the family have a diet that consists of fruit, supplemented by seeds, nectar, pollen, insects and spiders (Table 2.6). They are opportunistic and have a broad and varied diet. In terms of habitat, most live in forest, savanna, scrub and thickets. The Pycnonotidae also occur in secondary regrowth and in gardens. Wherever human-induced habitat transformation has resulted in scrubby or thickened habitats, the Pycnonotidae soon colonize it. This is probably one of the main reasons why bulbuls in general are doing so well in South Africa.

One invasive species which is characteristic of disturbed habitat and regrowth is *Lantana camara*; this South American species is an invasive plant in many parts of the world and was classified as the worst invasive plant in South Africa by Robertson et al. (2003). The main agents of distribution of seeds are frugivores, with the Pycnonotidae being one of the most important vectors (Vivian-Smith et al. 2006, Vardien et al. 2012, Mokotiomela et al. 2013).

Over much of the savanna biome areas across South Africa there has been a general thickening of vegetation (bush encroachment) (Timm Hoffman pers. comm.). This is partly due to land-use change and partly because of increased carbon-dioxide levels in the atmosphere; this is thought to be more favourable for the growth of trees and shrubs than for grasses (Timm Hoffman pers. comm). In addition, marginal arable land has been abandoned in many areas, and regrowth is taking place. Bulbuls are benefitting from orchards, gardens and farmyards. Across parts of the arid western parts of South Africa, dry watercourses are becoming lined with riverine bush (Timm Hoffman pers. comm.) and see, for example, studies by Hoffman and O'Connor (1999) and Hoffman and Rohde (2011). The westward expansion of the African Red-eyed Bulbul *Pycnonotus nigricans* across the Northern Cape (Figure 2.3) is probably explained by this phenomenon. There are thus likely to be many factors driving the increase of bulbul range and reporting rates.

Cisticolidae

The Cisticolidae are small 'warblers' with thin straight bills. Their plumage is usually cryptic. Most species are sedentary in woodland, shrubland, grassland and reedbeds (Hockey et al. 2005). These birds are mainly insectivorous, gleaning prey from foliage. Most members of the Cisticolidae are monogamous. Nests are mostly closed ovals with a side-top entrance, made from fine grass and other fibres, and built by both sexes, but mostly the female. They lay between one and six eggs in a clutch; chicks are altricial (Hockey et al. 2005). In southern Africa, Cisticolidae are represented by 37 species, of which 20 had a range of 100 QDGCs or more in the study area, and hence were included in this analysis (Table 2.7, Figure 2.4).

The Cisticolidae (cisticolas and African warblers) family appears to have done particularly well (Table 2.2). It is likely that part of the increased reporting rates overall for this family are attributable to improved identification skills of observers, and the availability of better field guides, with Peacock (2012) being the lead example. However, there are increased reporting rates for species in this family that were considered relatively easy to identify at the time of SABAP1 (for example, Levaillant's Cisticola *Cisticola tinniens*, Rattling Cisticola *Cisticola chiniana*, Croaking Cisticola *Cisticola natalensis*, Neddicky *Cisticola fulvicapilla*, Tawny-flanked Prinia, Bar-throated Apalis *Apalis thoracica*, Yellow-breasted Apalis *Apalis flavida*). Berruti (1997) listed five species of "grass cisticolas" that were regarded during SABAP1 as being the most difficult to distinguish: Zitting *Cisticola juncidis*, Desert *Cisticola aridulus*, Cloud *Cisticola textrix*, Wing-snapping *Cisticola ayresii* and Pale-crowned *Cisticola cinnamomeus*. For these species in particular, my analysis cannot distinguish how much of the increase in reporting rates for these species in Table 2.7 is attributable to improved identification skills of observers, and how much is attributable to change in habitats.

The Tawny-flanked Prinia had the highest probability of a QDGC having increased reporting rates within its range at 75.6% (Table 2.7). Its preferred habitat includes scrub, tall grass, woodland, forest edges, and overgrown gardens (Table 2.7). Berruti (1997) specifically mentioned "secondary thickets" and stated "This common species readily adapts to modified habitats, suburban environments and secondary vegetation." This suggests that the Tawny-flanked Prinia will benefit from the major changes taking place across its range, in particular the secondary growth associated for example with the abandonment of marginal farmland.

The Namaqua Warbler *Phragmacia substriata* had the lowest probability of QDGCs having increased reporting rates within it range at 44.8%, close to the overall average for all species of 47.6%; it was an outlier relative to the remaining species in the family with the second smallest value being 8.3% larger (Table 2.7).
The reason for this low probability is likely to be due to the region where the Namaqua Warbler occurs. The main part of its range covers the arid Karoo area of the Northern and Western Cape provinces. In spite of occurring in a generally arid

zone, its habitat preference is restricted to areas near water, such as streams and rivers, and these have not increased (Table 2.7).

Apart from the five “grass cisticolas” (Berruti 1997), the range preferences for almost all of the remaining 19 cisticola species have a habitat component which, either explicitly or implicitly in Peacock (2012), includes shrubland and thicket habitats (Table 2.7). All had increased reporting rate values exceeding 53.1% and five species had values exceeding 70% (Table 2.7). Bush encroachment, and the general increase in thicket associated with secondary and regenerating habitats is likely to be the most parsimonious explanation of the relatively large proportions of QDGCs with increased reporting rates for this family.

Ploceidae

Like the Pycnonotidae and the Cisticolidae, the enormous increase in Ploceidae must be associated with improved habitat and food. The results for these three families suggest that the most important and widespread factor impacting bird distributions in the two-decade period between SABAP1 and SABAP2 has been bush encroachment.

The Family Ploceidae contain small to medium sized sparrow-like birds. They are mostly sedentary or nomadic; some species are migratory (Hockey et al. 2005). The members of this family live in a wide variety of habitats, ranging from forest and wetlands to grassland and semi-desert (Hockey et al. 2005). Their diets vary from mainly granivorous (seed eating) with a small proportion being largely insectivorous. Many weavers also eat fruit and nectar. They are social and gregarious birds with monogamous, polygamous and some cooperative breeding systems (Hockey et al. 2005). Nests are usually ovals, ranging from neatly woven structures to an untidy collection of twigs, with the exception being the colonial nest of the Sociable Weaver *Philetairus socius*. Nests are usually built by the male. Between two and eight eggs are laid and chicks are born altricial (Hockey et al.

2005). The female alone usually incubates the eggs, but nestling are fed by both adults. In southern Africa this family is represented by 29 species.

For the 22 species of weavers with more than 100 QDGCs occupied, the increase reporting rate percentages ranged between 40.6% and 80.8% (Table 2.8). All except one of the 10 species with increased reporting rate percentages greater than 70% have habitat descriptions that specifically mention habitat types that are associated with bush thickening, such as thicket, thornveld, riverine vegetation and savanna (Table 2.8). The exception is the Southern Red Bishop, a species associated with "open grassland, marshes and cultivated areas," these are all habitats thought to be decreasing. However, the limiting habitat for this species in the past might have been reedbeds in which to breed; because it was an agricultural pest, drainage of wetlands and destruction of reedbeds were a deliberate strategy to reduce numbers in farmland areas (Craig 1997a). It is possible that the increased abundance of Southern Red Bishops is attributable to abandonment of small-scale farming, and an associated decrease in the deliberate destruction of reedbeds at small farm dams and at wetlands.

Accipitridae

The Family Accipitridae is a diverse group of raptors that are divided into two subfamilies: Pandioninae (with one species, Osprey *Pandion haliaetus*) and Accipitrinae (all the other species including Old World vultures, kites, buzzards, harriers, hawks and eagles). These birds have hooked bills adapted for tearing flesh and they have toes with strong, curved nails (except vultures) for striking and killing prey (Hockey et al. 2005). The Accipitridae include sedentary and migratory species and occur in a wide variety of habitats and altitudes. They are capable fliers; vultures and eagles soar to great heights, woodland and forest species manoeuvre in fast flight through the tree canopy in pursuit of their prey (Hockey et al. 2005). These birds mainly feed on animal prey, mostly vertebrates that are live-caught, but some species, notable vultures, feed mainly on carrion (Hockey et al.

2005). Some are dietary specialists. Ospreys and African Fish Eagles *Haliaeetus vocifer* are almost exclusively piscivorous (fish-eaters), Bat Hawks *Macheiramphus alcinus* feed mainly on bats, snake eagles *Circaetus spp.* on reptiles, and honey-buzzards *Pernis* spp*.* on wasps (Hockey et al. 2005). Most species are monogamous and build platform nests that are often reused in successive years. Nests are built in trees, on cliff or on the ground. They lay between 1 and 5 eggs, siblicide (killing of siblings) is common in the large species that hatch more than one young. Parental care is undertaken by both sexes. Incubation and nesting periods are prolonged in the large species, which may only breed biennially (Hockey et al. 2005). In southern Africa, this family is represented by 54 species.

The Accipitridae were selected for consideration here because they represent a family which shows a large range in the probability of increased reporting rates, from 18.7% (Tawny Eagle *Aquila rapax*) to 62.2% (Long-crested Eagle *Lophaetus occipitalis*) (Table 2.9). The mean probability of increased reporting rate for QDGCs with the range of an accipiter species was 39.6%, the lower quartile was 31.6%, and the upper quartile was 47.1%. This pattern of large variability within this family contrasts strongly with the three families considered earlier, in which most species within the family showed similar values. Each species could be explored in detail; this discussion focuses on four of the species in Table 2.9.

The Tawny Eagle and Bateleur *Terathopius ecaudatus* are among the most threatened eagles in southern Africa, with the core of their ranges becoming more confined to major protected areas and areas with low densities of human habitation (Simmons 1997a, b). Tawny Eagles often scavenge and this makes them non-target victims of farmers who indiscriminately put out poisoned bait for small livestock predators like Black-backed Jackals *Canis mesomelas* and Caracal *Caracal caracal* (Simmons 1997b). Bateleurs on the lookout for food are usually among the first raptors to detect carrion, including poisoned bait (Simmons 1997a). In South Africa it now breeds almost exclusively in the Kruger and Kgalagadi National Parks and

nearby conservation areas. This shows that Bateleurs are sensitive to disturbance by humans. There is unequivocal evidence that Bateleurs have decreased because of indiscriminate poisoning by livestock farmers (Simmons 1997a).
In general it looks likely that those raptors which feed on mammals are doing worse than those that rely on other sources of food (Chapter 3).

However, it is striking that both Tawny Eagles and Bateleurs showed decreased reporting rates in most QDGCs across the Kruger National Park (Figure 2.5). This park is so large that spill-over effects of poisoning from neighbouring farmland are an unlikely explanation of the declines in these species. Both species have one characteristic in common; they are primarily scavengers (Simmons 2005a, b). Indeed, Watson (1988) estimated that adult Bateleurs found 75% of their food items by scavenging dead animals and younger birds found 80% in this way. It is worth investigating whether the general thickening of vegetation that has taken place in the Kruger National Park has made it more difficult for flying scavengers to find food, and that this is the reason for the decline of these species in this protected area (Eckhardt et al. 2000).

For the Martial Eagle *Polemaetus bellicosus*, Boshoff (1997) wrote that “the population numbers for this species had decreased locally in many areas, often dramatically, but that the Martial Eagle was still widespread in southern Africa”. The main reasons, for their decline, outside of protected areas are indirect persecution by poisoned bait and direct persecution in the form of shooting and trapping by small-stock farmers (Boshoff 1997). The overall consensus two decades ago was that populations of birds of prey such as the Martial Eagle were stable in the Kruger National Park and other large conservation areas. In fact, in the 2000 Red Data Book, the hope was expressed that the large conservation areas could act as source areas for recolonization once landowners' attitudes towards birds of prey had become more tolerant (Barnes 2000). But closer inspection suggests that even in these areas Martial Eagles are not doing well (Figure 2.6). The insert in Figure

2.6 shows the north-eastern corner of South Africa, including the Kruger National Park. The map compares the reporting rates between SABAP1 and SABAP2 for each QDGC. For most of these quarter degree grid cells large numbers of checklists were submitted for both atlas projects. Therefore the reporting rates are likely to be fairly well estimated. Orange is the most abundant colour on the map (Figure 2.6), which indicates a decrease in reporting rates. Some of these changes are so large that they cannot be attributed to differences in protocol between SABAP1 and SABAP2 alone. The largest changes are from SABAP1 reporting rates of 96.8% to 0% in SABAP2, and from 82.4% to 5.3% (Underhill 2012).

This pattern of decreased reporting rates within the Kruger National Park which is evident for Tawny Eagles and Bateleurs is also evident for Martial Eagles. However, Martial Eagles are primarily hunters, not scavengers (Boshoff 1997, Simmons 2005c). It hunts by soaring to relatively high altitudes and spots prey on the ground at long distances (Simmons 2005c). As for the Tawny Eagle and the Bateleur, bush thickening might also have been the primary explanation for the decrease in the Kruger National Park, and for essentially the same reason: thickening reduces visibility of prey to flying predators. Boshoff (1997) hinted that this is a possible explanation: “It avoids densely wooded and forested areas.”

At the other extreme, the Long-crested Eagle is doing particularly well (Table 2.9, Figure 2.7). Remarkably, this was a species listed as “rare and endangered” in the first Red Data list for birds in South Africa (Siegfried et al. 1976). By the 1980s it has extended its range westward into the previously treeless grassland regions of KwaZulu-Natal Province with the spread of commercial afforestation (Jenkins 1997), a process which is clearly still continuing (Figure 2.7). The green on the map in Figure 2.7 shows QDGCs where reporting rates for Long-crested Eagle have increased since SABAP1. The green areas in this map also include areas where bush encroachment has taken place since SABAP1. The blue QDGCs in Figure 2.7 have been colonized since SABAP1; some of these will be associated with commercial afforestation. However, the colonization of Gauteng shown in Figure 2.7 in the past two decades must be associated with an adaptation to making use of trees in suburban gardens.

Sagittariidae

The Sagittariidae family is monotypic, containing only one species, the Secretarybird *Sagittarius serpentarius* (Hockey et al. 2005). The Secretarybird is a large, long-necked raptor. Their unusually long legs are adapted for hunting on the ground (Hockey et al. 2005). They are sedentary birds and are usually solitary or in pairs, hunting in savanna and other open habitats (Hockey et al. 2005). They mainly eat insects and small vertebrates like reptiles. Secretarybirds are monogamous and build large platform nests on treetops (Hockey et al. 2005). The nest is typically built on top of a thorny tree; indigenous tree species include black thorn *Acacia mellifera*, umbrella thorn *Acacia tortilis*, sweet thorn *Acacia karroo* and common hook thorn *Acacia caffra*, and they also breed on alien trees such as Black wattle *Acacia mearnsii* and pine *Pinus* spp (Hockey et al. 2005). Secretarybirds lay one to three eggs, which are mainly incubated by the female for about 40–46 days, while the male feeds her at the nest. The chicks, born altricial, are fed by both adults.

There is a downward trend in the population of Secretarybirds, and the species was classified as Vulnerable globally on the IUCN Red List in 2011 (BirdLife International 2013c). The consistent decrease in bird atlas reporting rates for the Secretarybird in a large proportion of QDGCs (Figure 2.8) points to a decreased abundance across most of its South African range in the two decades between the two atlas projects. A great cause for concern is the almost uniformly decreased reporting rates throughout the Kruger National Park, which is South Africa's largest formally protected area. For many raptors and other large, threatened bird species the Kruger National Park is considered to be an important refuge and stronghold (Hockey et al 2005). This area also has very good data coverage in terms of the number of bird checklists submitted in both atlas projects, which adds considerable weight to the conclusion that this decrease in reporting rates represents a real decrease in abundance (Hofmeyr 2012).

It is possible that changes in vegetation composition and structure have brought about this decline in the park. Between 1940 and 1998 the total number of small to medium-sized shrubs and bushes increased over much of Kruger National Park (Eckhardt et al. 2000) and this trend is likely to have continued since 1998, based on findings for other parts of South Africa and other conservation areas (Wigley et al. 2009). Secretarybirds prefer open habitats, for this reason bush encroachment may have made much of the habitat unsuitable for this bird. The global trend of increasing atmospheric carbon dioxide levels has been linked to the general increase in woody vegetation at the expense of grassland and savannas across South Africa and globally, and this is predicted to continue (Wigley et al. 2010). Bush encroachment may therefore constitute a major threat to the Secretarybird.

Ciconiidae

The Ciconiidae are large to very large long-legged birds, which are mostly associated with aquatic habitats. Species in this family are sedentary or migratory and most of them occur in wetlands, where they eat fish and other aquatic animals (Hockey et al. 2005). The species in the genus *Ciconia* are mainly terrestrial, feeding on insects, whereas the species in the *Leptoptilos* genus are terrestrial and aquatic omnivorous scavengers that include carrion in their diet (Hockey et al. 2005). Most members of this family stalk their prey; the species in the genus *Mycteria* also hunt by scything a partly open bill back and forth in muddy water. The Ciconiidae are monogamous with complex displays during breeding season (Hockey et al. 2005). They nest colonially or singly, making large stick nests in trees or on cliffs. They usually lay three to five eggs that are incubated by both sexes. Chicks are altricial with two coats of down. In southern Africa, Ciconiidae is represented by eight species.

The Ciconiidae was also a family which showed a large range in the mean probability of increased reporting rates, ranging from 14.9% (Abdim's Stork *Ciconia abdimii*) to 72.6% (African Openbill *Anastomus lamelligerus*) (Table 2.10).
The Black Stork *Ciconia nigra* exhibited large decreases in reporting rates across South Africa. The majority of the world's Black Stork population breeds across central Eurasia, and migrates south, but they stay north of the equator (del Hoyo et al. 1992). The population in southern Africa is an isolated breeding population. The Black Stork is similar to the European Bee-eater *Merops apiaster*, a northern migrant, in that they both have isolated breeding sub-populations in the south. There are also a small number of White Storks *Ciconia ciconia* that breed in South Africa, but this population has never established itself as successfully as the Black Storks have (Underhill 2013). But, the range-change map comparing SABAP1 with SABAP2 shows that the southern African population of the Black Stork is in sharp decline (Figure 2.9). The evidence is shown by all the red grid cells (do not occur in these QDGCs anymore) and orange grid cells (decreased since SABAP1) in Figure 2.9. This is one of the largest decreases in range recorded by SABAP2 (Underhill 2013). The Black Stork case study supports the assertion that SABAP2 is one of the most important conservation initiatives in the southern African region. If it were not for SABAP2, the Black Stork might have disappeared entirely before we became aware of its decline. It is of utmost importance for conservation management decisions that we have information about ranges of species and how they are changing (Underhill 2013).

In the 2000 Red Data Book for South Africa, Lesotho and Swaziland, the Black Stork was classified as Near-threatened. The Black Stork's montane breeding habitat is not under threat (Barnes 2000). This species is, however, dependent on shallow waterbodies such as estuaries and rivers where it forages for fish, amphibians and a range of aquatic invertebrates (Barnes 2000). Barnes (2000) reports that "wetland conversion in the form of degradation of estuaries and highland marshes, the afforestation of catchments which reduces water inflow and the damming of smaller rivers are causes for concern. The species is susceptible to poisoning and is highly prone to disturbance so it tends to avoid contact with people". Therefore it was concluded that Black Storks may suffer a decline in the near future and, because of its small breeding population here in South Africa, it requires monitoring (Barnes 2000). The monitoring, however, did not take place, and it has taken SABAP2 to alert us to the reality that this species is now in real trouble. The Black Stork is very sensitive to human disturbance, and is particularly sensitive to disturbances at their nest sites. In fact, one of the factors common to many of the species showing range reductions between SABAP1 and SABAP2 is a lack of tolerance to human disturbance (Underhill et al. 2013).

The African Openbill, surprisingly, has shown increased reporting rates compared to the other members of the Ciconiidae family. The African Openbill is an intra-African trans-equatorial migrant (del Hoyo et al. 1992). This species' movements are triggered by the rains (Hancock et al. 1992). They breed during the rainy season when their main prey items, snails, are available in abundance and they nest in colonies of various sizes (del Hoyo et al. 1992, Hancock et al.1992). Nesting may only occur in years when there is enough food available locally, for this reason they do not always return to the same nesting sites (Hancock et al. 1992). This suggests that African Openbills might follow a boom-bust cycle depending on food availability and that their increased reporting rates might be a result of a few years of good breeding success due to large amounts of prey availability.

Scopidae

The Family Scopidae is monotypic, containing only one species, the Hamerkop *Scopus umbretta*. The Hamerkop is a medium sized water bird with a long, heavy, laterally compressed bill. They are sedentary birds, usually associated with wetlands where they feed on amphibians, fish and other animals. Hamerkop are monogamous and build a huge, domed nest of sticks in trees or on cliffs (Hockey et al. 2005). They lay three to six eggs, which are incubated by both adults for about 26–30 days. Chicks are born altricial. The Hamerkop occurs in south-western Arabia, Madagascar and sub-Saharan Africa. It is locally common across southern Africa, although scarce to absent in the arid western region (Hockey et al. 2005). The Hamerkop mainly preys on the adults and tadpoles of platanna frogs, which belong to the genus *Xenopus*. The Common Platanna *Xenopus laevis* has a very similar distribution (Figure 2.10) to that of the Hamerkop, suggesting that it is dependent on Common Platannas for food. It also eats other frogs, small fish and insects, using a variety of foraging techniques (Hockey et al. 2005).

The Common Platanna is a widespread and common species, within its southern distribution, where it occurs from sea level to almost 3000 m above sea level in Lesotho (Minter et al. 2004). In the Northern Cape Province of South Africa, it is absent in the highly arid areas, such as large parts of the Kalahari and Bushmanland (Minter et al. 2004). In the east the Common Platanna's distribution stretches as far as the Great Escarpment, here its range overlaps with Müller's Platanna *Xenopus* muelleri, but only in the low-lying parts of Mpumalanga and Limpopo provinces (Minter et al. 2004). Before the arrival of modern agriculture, the Common Platanna probably occurred in low densities in natural water bodies, such as temporary pools, streams, and rivers (Minter et al. 2004). At present this species is also found in a variety of man-made water bodies such as fish farms, farm dams, ponds, and sewage purification works (Minter et al. 2004). The Common Platanna does not seem to be threatened in any part of its range. It has actually proven to be a highly invasive species, as is shown by introduced populations that have established themselves in many parts of the world (Minter et al. 2004). There is a recent review showing that *Xenopus laevis* is actually increasing its range (Measey et al. 2012). Therefore, the Hamerkop's dependence on platannas as a food source cannot be the reason behind its decline (Figure 2.11). Figure 2.11 shows that reporting rates for Hamerkop have decreased throughout most of its range.

The deterioration of wetland water quality, because of the excessive use of pesticides near these areas, poses a potential threat to the Hamerkop (del Hoyo et al. 1992). The species is hunted for trade at traditional medicine markets in Nigeria (Nikolaus 2001). The Hamerkop also seems particularly sensitive near its nesting sites. The nest is typically placed in a tree over or next to water, occasionally on a bridge, dam wall, or sometimes on the ground (Hockey et al. 2005). Other animals often claim Hamerkop nests for themselves, such as bees, reptiles and other birds, including Barn Owls *Tyto alba* and Black Sparrowhawks *Accipiter melanoleucus* (Hockey et al. 2005).

Bucorvidae

The Bucorvidae family is monogeneric, containing only one genus, *Bucorvus*. The ground hornbills are endemic to sub-Saharan Africa and are the largest hornbills as well as among the largest of all flying birds (Hockey et al. 2005). There are two species: the Northern (Abyssinian) Ground Hornbill *Bucorvus abyssinicus*, which occurs from Senegal in the west, across the Sahel to Ethiopia in the east; and the Southern Ground Hornbill *Bucorvus leadbeateri*, which occurs in southern and east Africa. The Southern Ground Hornbill occurs in grassland and savanna habitat with large trees and rock faces. Ground hornbills are largely terrestrial, spending most of their time walking, but they are strong fliers (Hockey et al. 2005). They are mainly carnivorous, eating insects, frogs, mongooses and bird nestlings. They forage in groups, so when one bird locates a prey item it can signal the rest of the flock with a low bark. Southern Ground Hornbills are monogamous, cooperative breeders, with a group consisting of a dominant breeding pair and up to nine helpers, who are either adult males or juveniles from previous breeding seasons (Hockey et al. 2005). They roost in trees on rock faces, descending to the ground just before dawn and spend most of their time foraging throughout the day. Nests are usually cavities in trees lined with dry leaves. One to two eggs are laid, which are incubated solely by the female for 37–43 days (Hockey et al. 2005). The eggs hatch in the sequence that

they were laid; this means that the one chick is 3–14 days older than the other. The younger chick is usually unable to compete for food with its older sibling and dies of starvation when it is about one week old (Hockey et al. 2005).
The fledging leaves the nest when it is approximately 86 days old and remains with its parents for several years (Hockey et al. 2005).

Of all species considered in this analysis, the Bucorvidae, represented by the Southern Ground Hornbill, showed the smallest percentage of range where reporting rates had increased; the value was 13.8% (Tables 2.2 and 2.10). Many of these increases would most likely be apparent increases only, and be attributable to small sample sizes.

Southern Ground Hornbills face many and most often complex threats. These birds naturally occur at low densities and each family group requires a large territory. The size of the territory is determined by habitat quality. In the Kruger National Park and KwaZulu-Natal midlands, these territories are about 100 km^2, in the drier Limpopo River valley the territories increase to about 250 km^2, but among the moist woodland savannas of Mana Pools, Zimbabwe and Niassa, Mozambique family groups can manage with territories as small as 60 km^2 (Kemp 2013). Southern Ground Hornbills are slow breeders and they have a long lifespan. They only reach sexual maturity at around eight years of age, and their complex cooperative breeding structure means that only the one alpha pair in a group forms the breeding unit (Kemp 2013). These life history traits make Southern Ground Hornbills particularly vulnerable to environmental change or persecution. Studies from the Kruger National Park revealed that, on average, groups successfully raised only one chick every nine years. Artificial nest sites, however, has helped to improve to the breeding rate (Kemp 2013).

Southern Ground Hornbills face a variety of anthropogenic threats. Loss of habitat plays a major role in the viability of a population. As human settlements expand, these birds have less space in which to breed and forage. They lose suitable nesting trees and suitable foraging sites. The demand for firewood and timber, the expansion of monoculture crops and plantations, overgrazing, poor fire management practices and bush encroachment are all having a negative impact on Southern Ground Hornbills (Kemp 2013). The Southern Ground Hornbill is very territorial, they have a tendency to break windows by attacking their own reflection in glass, and for this they get persecuted directly (del Hoyo et al. 2001). They are persecuted indirectly by consuming poisoned bait, and they are sometimes killed because of cultural myths as a measure against drought as well as being harvested from the wild by private collectors and zoos (del Hoyo et al. 2001). Collisions with powerlines may also be a threat for these birds in South Africa (BirdLife International 2013a). Threats like these are aggravated by the slow reproductive rate and maturation of these birds, as well as their longevity and social structure (BirdLife International 2013a).

The red cells in Figure 2.12 show the areas where Southern Ground Hornbills have shown significant decreases in reporting rates between SABAP1 and SABAP2. The red areas are areas of significant decrease and these areas also correspond with the areas where bush encroachment has taken place (Timm Hoffman pers. comm.). The threat to Southern Ground Hornbills posed by bush encroachment and bush thickening is the increased risk of “ambush predation” (Lucy Kemp pers, comm.). They are large birds (4 kg) and even though they fly strongly, they are not able to take off rapidly to escape predators detected within a few seconds prior to being attacked. They avoid predation by feeding in vast grassland areas or in savanna with a sparse understory (Table 2.10).

Conclusions

An important theme running through this chapter is the realization that bush encroachment is an important factor, and almost certainly the most important factor, in driving the range dynamics of bird species in southern Africa. The first study to address this issue is that of Sirami and Monadjem (2012). The study was conducted at four sites in the savanna biome in Swaziland where, over a period of 10 years, bush and shrub cover increased from 37% to 66% and grass cover decreased from 63% to 34%. Of 106 bird species recorded during their study, 32 species showed increases and 29 species decreases. They were able to demonstrate that bush and shrub encroachment and loss of grassland were the key variables explaining the changes in bird community structure. The study by Sirami and Monadjem (2012) claims that it presents the first quantitative evidence of, as opposed to anecdotal concern for, the impact of bush encroachment on bird communities in southern Africa. They conclude that loss of open grassland habitat within the savanna biome is likely to become an urgent conservation issue. This chapter confirms these findings.

Table 2.1 Analysis of deviance table for the generalized linear model with Family as explanatory variable. The distribution was binomial, with the ranges (QDGCs) of 514 species as the sample sizes, and number of QDGCs in which the reporting rate of the species had increased as the dependent variable. The percentage of deviance explained is 46.6% as computed by GenStat (100 × (Regression deviance.)/(Total deviance))

Source	Degrees of freedom	Deviance	Mean deviance	Deviance ratio
Regression	78	10064	129.02	129.02
Residual	435	11546.	26.54	
Total	513	21609.	42.12	

Table 2.2 Back-transformed probabilities from the generalized linear model of Table 2.1. There was a single explanatory variable, Family. The families have been ordered from largest to smallest estimated proportion of grid cells with increase in reporting rate between SABAP1 and SABAP2 (see text)

Family	Percentage increasing
Pycnonotidae (bulbuls, greenbuls, brownbuls, nicators)	66.34
Cisticolidae (cisticolas and African warblers)	65.97
Ploceidae (weavers, queleas, widowbirds)	61.56
Haematopodidae (oystercatchers)	58.93
Hirundinidae (swallows and martins)	57.00
Lybiidae (African barbets and tinkerbirds)	56.57
Malaconotidae (bush-shrikes, boubous, tchagras, batises)	56.27
Motacillidae (wagtails, pipits and longclaws)	54.75
Passeridae (sparrows, petronias)	54.58
Campephagidae (cuckoo-shrikes)	54.23
Struthiodae (ostrich)	54.21
Sylviidae (leaf-warblers, babblers, warblers)	53.65
Picidae (woodpeckers, wrynecks)	53.61
Fringillidae (canaries and buntings)	53.48
Collidae (mousebirds)	53.43
Apodidae (swifts)	52.88
Nectariniidae (sunbirds)	52.13
Meropidae (bee-eaters)	51.66
Sturnidae (starlings, mynas, oxpeckers)	50.80
Muscicapidae (thrushes, robins, chats, Old World flycatchers)	50.73
Laniidae (typical shrikes)	50.45
Corvidae (crows and ravens)	50.38
Phoeniculidae (wood-hoopoes)	50.27
Numididae (guineafowls)	50.23

Family	Percentage increasing
Jacanidae (jacanas)	49.68
Indicatoridae (honeyguides)	49.48
Alaudidae (larks, sparrowlarks)	49.31
Cuculidae (Old World cuckoos)	49.18
Anatidae (ducks, geese)	49.04
Columbidae (pigeons and doves)	48.98
Dicururidae (drongos)	48.61
Monarchidae (crested-flycatchers, paradise-flycatchers)	48.59
Paridae (tits, penduline-tits)	48.46
Rhinopomastidae (scimitarbills)	48.27
Dendrocygnidae (whistling ducks)	48.07
Sulidae (gannets and boobies)	47.50
Estrildidae (twinspots, firefinches, waxbills, finches)	47.32
Viduidae (whydahs, indigobirds (cuckoo finch)	47.27
Musophagidae (turacos, louries)	47.18
Threskiornithidae (ibises and spoonbills)	46.97
Podicipedidae (grebes)	46.41
Dacelonidae (dacelonid kingfishers)	46.13
Oriolidae (orioles)	46.13
Rallidae (rails, crakes, flufftails, gallinules, moorhens and coots)	45.85
Phalacrocoracidae	44.17
Phasianidae (francolins, spurfowls, quails)	43.99
Charadriidae (plovers, lapwings)	43.04
Anhingidae (darters)	42.12
Falconidae (falcons and kestrels)	40.99
Recurvirosridae (avocets and stilts)	40.95
Laridae (skuas, jaegers, gulls, terns, skimmers, noddies)	40.34
Alcedinidae (alcedinid kingfishers)	39.93

Family	**Percentage increasing**
Heliiornithidae (finfoots)	39.85
Accipitridae (vultures, kites, hawks, eagles, buzzards and harriers)	39.31
Otididae (bustards and korhaans)	38.50
Phoenicopteridae (flamingoes)	38.07
Rostratulidae (Painted snipe)	36.76
Pteroclidae (sandgrouse)	36.63
Burhinidae (thick-knees, dikkops)	36.25
Upupidae (Hoopoe)	36.11
Trogonidae (Narina trogon)	35.80
Ardeidae (herons, egrets and bitterns)	35.75
Gruidae (cranes)	35.56
Centropodidae (coucals)	35.06
Glareolidae (coursers and pratincoles)	35.05
Bucerotidae (hornbills)	34.72
Promeropidae (sugarbirds)	33.82
Turnicidae (buttonquails)	33.43
Pelecanidae (pelicans)	32.14
Coraciidae (rollers)	30.37
Tytonidae (Barn owl, Grass owl)	30.21
Caprimulgidae (nightjars)	30.15
Cerylidae (cerylid kingfishers)	29.96
Strigidae (typical owls)	28.21
Scolopacidae (turnstones, sandpipers, stints, snipe and curlews)	28.09
Sagittariidae (secretarybird)	25.46
Ciconiidae (storks)	25.23
Scopidae (hamerkop)	18.40
Bucorvidae (ground hornbill)	13.81

Table 2.3 The results of subsampling the study area, in an attempt to investigate the impact of spatial autocorrelation on the results of fitting family as explanatory variable

Retained proportion of data	Nearest distance between retained cells	Number of quarter degree grid cells	Percentage deviance explained
Full	0.25	1399	46.5%
Half	0.35	697	46.4%
Quarter	0.50	349	43.9%
Eighth	0.71	182	42.4%
Sixteenth	1.00	88	34.9%

Table 2.4 The empirical variogram at lag distances ranging from 0.25 degrees to 3 degrees for a selection of species. The number of observations is the range of the species within the 1399 quarter degree grid cells with four or more checklists for both SABAP1 and SABAP2. Percentage up refers to the percentage of these QDGCs for which the reporting rate for the species had increased between SABAP1 and SABAP2. The overall variance is obtained from the fitted empirical variogram (see text)

Species	**316**	**387**	**402**	**430**	**576**	**707**	**734**	**803**	**805**
Species name	Cape Turtle Dove	African Palm Swift	Brown-hooded Kingfisher	Southern Ground Hornbill	African Stonechat	Common Fiscal	Common Myna	Southern Masked Weaver	Red-billed Quelea
Observations	1394	652	853	210	1202	1376	627	1330	1070
Percentage up	54.0	83.4	44.7	13.8	55.9	47.2	84.9	74.9	80.8
Overall Variance	0.2486	0.1384	0.2474	0.1196	0.2467	0.2494	0.1288	0.1882	0.1550
Lag distance									
0.25	0.2609	0.1176	0.1977	0.1667	0.1905	0.2015	0.0482	0.1343	0.1481
0.50	0.2039	0.1331	0.2143	0.1147	0.1955	0.2109	0.0597	0.1542	0.1310
0.75	0.2232	0.1421	0.2212	0.1159	0.2043	0.2241	0.0671	0.1681	0.1388
1.00	0.2270	0.1459	0.2299	0.1145	0.2109	0.2311	0.0731	0.1674	0.1395
1.25	0.2309	0.1427	0.2331	0.1135	0.2115	0.2277	0.0768	0.1673	0.1354
1.50	0.2344	0.1440	0.2366	0.0992	0.2176	0.2294	0.0836	0.1722	0.1383
1.75	0.2405	0.1456	0.2357	0.1098	0.2235	0.2386	0.0857	0.1772	0.1358
2.00	0.2419	0.1506	0.2380	0.1081	0.2284	0.2391	0.0912	0.1775	0.1422
2.25	0.2407	0.1515	0.2415	0.1108	0.2318	0.2415	0.0982	0.1778	0.1436
2.50	0.2445	0.1546	0.2369	0.1072	0.2355	0.2457	0.1042	0.1785	0.1444
2.75	0.2462	0.1551	0.2436	0.0959	0.2389	0.2463	0.1099	0.1804	0.1461
3.00	0.2485	0.1536	0.2446	0.1019	0.2396	0.2433	0.1140	0.1827	0.1466

Table 2.5 Numbers of species in significance class categories in relation to the statistical test for random patterns of increase (see text)

Significance level	Number of species	Percentage of species
P<0.10	334	65.0
0.10≤P<0.05	50	9.7
0.05≤P<0.01	64	12.5
0.01≤P<0.001	29	5.6
P<0.001	37	7.2
Total	514	100

Table 2.6 *Pycnonotidae* (bulbuls, greenbuls, brownbuls) family arranged from lowest to highest probability of increase in reporting rate. Habitat and diet preference descriptions summarized from Hockey et al. (2005)

Species Name	P(Up)	Habitat Preferences and Diet
African Red-eyed Bubul *Pycnonotus nigricans*	61.11	Occurs in a wide variety of arid and semi-arid habitats, such as *Acacia* savanna, semi-arid shrublands, riverine bush and gardens in arid areas. Mainly eats fruit, supplemented with nectar, flowers and arthropods
Terrestrial Brownbul *Phyllastrephus terrestris*	61.41	Prefers undergrowth of thickly vegetated habitats, such as evergreen and riparian forest. Mainly eats arthropods, probing and overturning leaf litter in search of prey and may occasionally feed on *Aloe* nectar.
Dark-capped Bulbul *Pycnonotus tricolor*	66.62	Can occupy any habitat with adequate supply of fruiting trees and bushes, absent only from dense woodland or grassland with few bushes. It is particularly common in gardens, plantations and parks in and around human settlements. Eats a range of fruit, petals, nectar, seeds and arthropods.
Sombre Greenbul *Andropadus importunus*	69.09	Prefers coastal scrub and forest, or well-wooded valleys further inland. It also occupies thornveld, dry woodland thickets along drainage lines in the Karoo and gardens in well-wooded suburbs. Eats mainly fruit, foraging in the foliage of trees and bushes.
Cape Bulbul *Pycnonotus capensis*	71.79	Prefers thickly vegetated fynbos and succulent karoo, as well as coastal scrub, Sweet thorn *Acacia karoo* woodland, suburban parks and gardens. Mainly eats fruit, supplemented with arthropods, seeds and nectar.
Yellow-bellied Greenbul *Chlorocichla flaviventris*	78.72	Prefers thick tangled undergrowth, especially in clearings in riverine and coastal forest, miombo *Brachystegia* and mopane *Colosphermum mopane* woodland, gardens, mangroves and semi-arid bush. Mainly eats fruit, doing most of its foraging with other bulbuls in the lower canopy, gleaning food from leaves and branches.

Table 2.7 Cisticolidae (Cisticolas and African warblers) family arranged from smallest to largest probability of increase in reporting rate. Habitat preference descriptions summarized from Peacock (2012)

Species Name	P(Up)	Habitat Preferences
Namaqua Warbler *Phragmacia substriata*	44.79	Always near water, permanent streams and rivers, thick woodland bordering reeds and rushes
Barred Wren Warbler *Calamonastes fasciolatus*	53.07	Restricted to semi-arid Acacia dominated thornveld, bushveld, and savanna
Red-faced Cisticola *Cisticola erythrops*	53.07	Moist thickets, usually near water
Wailing Cisticola *Cisticola lais*	57.86	Treeless, grassy slopes, tall grass with scattered rocks and some bushes
Rufous-eared Warbler *Malcorus pectoralis*	59.04	Semi-arid Karoo plains with abundant scrub
Lazy Cisticola *Cisticola aberrans*	59.46	Steep, rocky slopes with mix of rocks, boulders, grass, shrubs, trees
Wing-snapping Cisticola *Cisticola ayresii*	62.79	Montane grassland, grazed pastures, airstrips, wetland edges
Levaillant's Cisticola *Cisticola tinniens*	63.31	Vleis, dams, streams with moist weedy vegetation, sedges
Croaking Cisticola *Cisticola natalensis*	63.41	Dense grassland with scattered bushes, moist or dry areas
Desert Cisticola *Cisticola aridulus*	65.35	Drier/sparser grassland, regenerating agricultural lands, woodland clearings, cattle grazing land
Yellow-breasted Apalis *Apalis flavida*	65.71	Wooded habitats, forest edges, secondary growth, savanna, thickets, parks, shady gardens
Cloud Cisticola *Cisticola textrix*	66.22	Short grass, open fynbos, cereal fields, renosterveld
Zitting Cisticola *Cisticola juncidis*	66.38	Moist grassland, open suburbia, golf courses, irrigated fields
Pale-crowned Cisticola *Cisticola cinnamomeus*	69.14	Moist, tall grass, wetland borders, edges of pans
Bar-throated Apalis *Apalis thoracica*	69.85	Wooded habitats with dense scrub, secondary growth, thickets, gardens, alien plants
Black-chested Prinia *Prinia flavicans*	70.19	Low scrubby vegetation, thornveld, grassland with scattered bushes, old agricultural fields, weedy patches, open gardens, road verges.

Species Name	**P(Up)**	**Habitat Preferences**
Neddicky *Cisticola fulvicapilla*	71.57	Sparse woodland, edges of plantations, farmyards, mountain fynbos
Rattling Cisticola *Cisticola chiniana*	73.29	Lightly wooded grassland, grassland with bush encroachment
Grey-backed Cisticola *Cisticola subruficapilla*	73.94	Semi-arid, scrub dominated areas, bushy grassland, edges of alien thickets, regrowth
Tawny-flanked Prinia *Prinia subflava*	75.55	Scrub, tall grass, woodland, forest edges, overgrown gardens

Table 2.8 *Ploceidae* (weavers) family arranged from smallest to largest probability of increase in reporting rate. Habitat and diet preference descriptions summarized from Hockey et al. (2005)

Species Name	P(Up)	Habitat Preference and Diet
Yellow Bishop *Euplectes capensis*	40.60	Occupies a wide array of habitats, including fynbos, cultivated land, and dense vegetation along streams, forest edges and montane grassland. Eats seeds supplemented with insects, doing most of its foraging on the ground and in patches of grass
Red-billed Buffalo Weaver *Bubalornis niger*	43.56	Prefers *Acacia* savanna, especially when it has been disturbed by humans and livestock. Eats insects, seeds and fruit, doing most of its foraging on the ground
Yellow-crowned Bishop *Euplectes afer*	47.14	In the breeding season it mainly occupies marshes or seasonally flooded areas, but when isn't breeding it can move into dry habitats such as cultivated areas. Mainly eats seeds taken from the ground or directly from plants
Red-headed Weaver *Anaplectes melanotis*	49.71	Prefers broad-leaved, especially miombo *Brachystegia* woodland, *Acacia* savanna, bushveld and gardens, usually of farms. Mainly eats arthropods, supplemented with seeds and fruit
Cape Weaver *Ploceus capensis*	50.27	Generally prefers open grassland, lowland fynbos, coastal thicket and farmland, provided they have permanent water and trees. Omnivorous, arthropods and plant matter, especially seeds, fruit and nectar
Dark-backed Weaver *Ploceus bicolor*	51.19	Favours forest and dense riverine vegetation in coastal thickets. Eats arthropods supplemented with fruit, nectar and flowers
Long-tailed Widowbird *Euplectes progne*	51.65	Prefers open grassland, breeding in tall grasses along watercourses or in marshy areas, but it may occur in grassy karoo or savanna at the extremity of its distribution. Eats seeds, supplemented with arthropods
Golden Weaver *Ploceus xanthops*	53.85	Prefers grassy thicket along forest edges, well-wooded savanna, riparian woodland, and rank vegetation along watercourses. Eats a variety of fruit, insects, seeds and nectar
Sociable Weaver *Philetairus socius*	54.11	Prefers arid savanna and woodland, although it may move into grassland, Mopane *Colosphermum mopane* woodland and the largely treeless Namib Desert, the latter permitted by the introduction of artificial structures which it uses as nest sites. Eats seeds, supplemented with termites and other insects

Species Name	**P(Up)**	**Habitat Preference and Diet**
Red-collared Widowbird *Euplectes ardens*	54.25	Favours savanna, tall grassland, scrub and cultivated land, generally more arid than other widowbird and bishop species. Eats grass seeds, supplemented with berries, nectar and insects
Scaly-feathered Finch *Sporopipes squamifrons*	56.42	Prefers dry *Acacia* woodland with scattered small trees, also in bushy vegetation along seasonal rivers, farmyards and suburban gardens. Eats the seeds of grasses (including *Aristida* and *Schmidtia*) supplemented with insects
White-winged Widowbird *Euplectes albonotatus*	59.71	Prefers habitats with rank vegetation and water, such as moist grassland and marshes, but also in disturbed areas and cultivated land. Eats the grass seeds, supplemented with nectar and insects
White-browed Sparrow Weaver *Plocepasser mahali*	61.93	Prefers semi-arid *Acacia* and Mopane savanna woodland, especially along the border between degraded and undisturbed habitat. Eats insects, seeds, fruit and fleshy leaves
Lesser Masked Weaver *Ploceus intermedius*	63.01	Prefers habitats with or close to water, such as *Acacia* savanna, open woodland, riverine trees, reedbeds, swamps and mangroves. Eats invertebrates (especially caterpillars) and nectar
Southern Red Bishop *Euplectes orix*	63.30	Generally prefers open grassland, marshes and cultivated areas, often near perennial water bodies. Mainly eats seeds and other plant matter, with invertebrates making up only about 0.5% of its diet
Fan-tailed Widowbird *Euplectes axillaris*	63.70	Prefers tall, moist grassland, marshes and cultivated areas (such as sugar cane fields). Eats grass seeds taken from the ground or directly from plants
Yellow Weaver *Ploceus subaureus*	66.39	Prefers river flood plains, coastal plains, estuaries and lowland river valleys, but it is mainly restricted to reedbeds and adjacent riverine vegetation while breeding. Eats seeds, insects and nectar
Spectacled Weaver *Ploceus ocularis*	68.73	Prefers well-wooded habitats with dense undergrowth, such as forest edges, woodland, vegetation along rivers in thornveld, bushed valleys and gardens. Eats insects supplemented with nectar and fruit
Village Weaver *Ploceus cucullatus*	69.01	Prefers woodland or forest along rivers, thornveld and parks and gardens, especially near water. Eats insects, seeds and nectar

Species Name	**P(Up)**	**Habitat Preference and Diet**
Thick-billed Weaver *Amblyospiza albifrons*	70.97	In breeding season it generally favours marshes, rivers, dams with rank grass, reedbeds and Papyrus *Cyperus papyrus* beds, but in non-breeding season it prefers edges and clearings in evergreen forest, also occupying reedbeds adjacent to ponds in suburban parks, alien plantations and cultivated areas. Eats fruit and seeds
Southern Masked Weaver *Ploceus velatus*	74.89	Favours semi-arid scrub, open savanna, woodland edges, riverine thicket, and farmland with scattered trees, alien tree plantations and gardens. Eats seeds, fruit, insects and nectar
Red-billed Quelea *Quelea quelea*	80.84	Most prolific in semi-arid habitats such as thornveld and cultivated land, but it may also occupy very wet or dry areas. Eats seeds of cereals and grasses, supplemented with arthropods

Table 2.9 Accipitridae (Vultures, Kites, Hawks, Eagles, Buzzards and Harriers) family arranged from smallest to largest probability of increase in reporting rate. Habitat and diet preference descriptions summarized from Hockey et al. (2005)

Species Name	P(Up)	Possible reasons for decline, habitat preference and diet
Tawny Eagle *Aquila rapax*	18.66	It suffers from both inadvertent and deliberate poisoning. Occurs in Nama Karoo and treeless grasslands, provided that there are pylons and alien trees to nest in. Predator, pirate and scavenger, feeding on a wide variety of animals
Bateleur *Terathopius ecaudatus*	21.80	Falls victim to persecution by humans as well as dying from poisoned bait put out for jackals. Prefers savanna and woodland habitats. Mainly a scavenger, feeding on wide variety of animals
Lizard Buzzard *Kaupifalco monogrammicus*	24.07	Indigenous woodland is its preferred habitat, local clearing of woodland restricts their habitat
Cape Vulture *Gyps coprotheres*	25.71	Poisoning, electrocution, extinction of migratory wild herds, habitat loss
Martial Eagle *Polemaetus bellicosus*	25.76	Direct persecution (shooting and trapping) by small-stock farmers, indirect by poisoning (poisoned bait for jackals)
Black-shouldered Kite *Elanus caeruleus*	26.02	Heavy use of agricultural pesticides has a detrimental effect, prefers cultivated land, grassland, and transformed fynbos. Eats rodents, small birds and lizards
Verreaux's Eagle *Aquila verreauxii*	27.83	Dassie populations (its main prey item) declining in certain areas due to hunting, persecution (shooting and trapping) by small-stock farmers
African Crowned Eagle *Stephanoaetus coronatus*	30.60	Persecuted by (shooting and trapping) stock farmers, makes use of stands of alien trees which brings them in contact with stock farmers
Black Harrier *Circus maurus*	31.37	Threatened by pesticide use, fynbos and grassland fires, and cereal harvesting
Shikra *Accipiter badius*	32.16	Occurs in all woodland types, will nest in dense copses of alien trees. Possible pesticide contamination
African Cuckoo Hawk *Aviceda cuculoides*	32.37	Occasionally makes use of suburban areas as well alien tree plantations

Species Name	**P(Up)**	**Possible reasons for decline, habitat preference and diet**
Rufous-chested Sparrowhawk *Accipiter rufiventris*	32.44	Uses alien trees for nesting
African Marsh Harrier *Circus ranivorus*	32.77	Wetland specialist, is threatened by habitat loss due to drainage of wetlands
Lappet-faced Vulture *Torgos tracheliotus*	33.33	Poisoned carcasses pose a particular threat
African Hawk Eagle *Aquila spilogaster*	34.80	Some shooting and trapping by poultry farmers, prefers Mopane woodland
Wahlberg's Eagle *Aquila wahlbergi*	38.17	Prefers well-wooded savanna as well as cultivated areas with tall trees, is threatened by poisoning
White-backed Vulture *Gyps africanus*	39.26	Vulnerable to poisoned carcasses
African Harrier Hawk *Polyboroides typus*	41.06	Incidents of direct persecution by pigeon-racing fraternities. Makes use of alien trees
African Goshawk *Accipiter tachiro*	41.45	Occurs in dense vegetation, exploits stands of alien trees for hunting and nesting
Gabar Goshawk *Melierax gabar*	42.13	Benefiting from bush encroachment in overgrazed areas and along watercourses
Little Sparrowhawk *Accipiter minullus*	42.54	Exploits stands of alien trees for breeding and hunting
Steppe Buzzard *Buteo vulpinus*	43.19	Makes use of plantations of alien trees for nesting
Jackal Buzzard *Buteo rufofuscus*	45.98	Prefers hilly or and mountainous areas with Karoo, fynbos, grassland, open woodland or semi-desert. Benefits from commercial afforestation. Eats mammals, supplemented with birds and lizards
Ovambo Sparrowhawk *Accipiter ovampensis*	46.55	Makes use of plantations of alien trees for nesting. It preys exclusively on birds. It has benefited from the abundance of birds associated with agriculture to feed on

Species Name	**P(Up)**	**Possible reasons for decline, habitat preference and diet**
Brown Snake Eagle *Circaetus cinereus*	46.94	Prefers wooded areas, vulnerable to habitat destruction, does better in protected areas than unprotected areas
Forest Buzzard *Buteo trizonatus*	47.09	Uses alien trees for nesting
Osprey *Pandion haliaetus*	47.71	Benefiting from dams that have been built
Black-chested Snake Eagle *Circaetus pectoralis*	48.66	Prefers open country, avoids mountainous and forested areas
S. Pale Chanting Goshawk *Melierax canorus*	52.23	Makes use of extensive farming areas
Booted Eagle *Aquila pennatus*	53.51	Makes use of a wide variety of habitats
African Fish Eagle *Haliaeetus vocifer*	57.24	Becoming more widespread due to the amount of dams that have been built, especially in arid areas
Black Sparrowhawk *Accipiter melanoleucus*	60.29	Its range has increased due to the spread of alien trees, which it commonly uses as nest sites
Montagu's Harrier *Circus pygargus*	61.54	Will nest in agricultural farmlands, it favours fence posts on which both male and female can rest and survey the breeding area
Long-crested Eagle *Lophaetus occipitalis*	62.15	Benefits from commercial afforestation, uses alien trees for nesting. May also occupy dry woodland, mixed farmland, pastures, edges of sugar-cane plantations and orchards

Table 2.10 *Sagittariidae (secretarybird), Ciconiidae (storks), Scopidae (hamerkop), and Bucorvidae (ground hornbill)* families arranged from smallest to largest probability of increase in reporting rate. Habitat and diet preference descriptions summarized from Hockey et al. (2005)

Species Name	P(Up)	Habitat Preference and Diet
Secretarybird *Sagittarius serpentarius*	25.46	Prefers open grassland with scattered trees, open *Acacia* and bushwillow *Combretum* savanna, shrubland, range lands, airstrips and other habitats with short grass. Mainly eats grasshoppers and small vertebrates. Local population decreases have been reported in South Africa
Abdim's Stork *Ciconia abdimii*	14.92	Prefers savanna woodland, grassland, pastures, pan edges, cultivated land and suburban areas. Mainly eats large insects, doing most of its foraging on pastures, irrigated land and recently ploughed fields. Destruction of natural grassland habitat has caused it to become reliant on agricultural land. Breeds in the Sahel zone just south of the Sahara
Black Stork *Ciconia nigra*	18.25	Can occupy almost any type of wetland, such as pans, rivers, flood plains, ponds, lagoons, dams, swamp forests, mangrove swamps, estuaries, tidal mudflats and patches of short grass close to water. Mainly eats fish. *Near-threatened* in South Africa and *Endangered* in Namibia
White Stork *Ciconia ciconia*	21.10	Prefers open woodland, grassy Karoo, grassland, wetlands and cultivated land. Eats a variety of insects and small vertebrates. Its breeding range has decreased in Europe
Yellow-billed Stork *Mycteria ibis*	27.34	Prefers wetlands, such as pans, flood plains, marshes, streams, flooded grassland and small pools, occasionally moving into mudflats and estuaries. Mainly eats fish, doing most of its foraging in shallow water without vegetation. *Near-threatened* in South Africa due to wetland disturbance and destruction
Marabou Stork *Leptoptilos crumeniferus*	36.05	Prefers open semi-arid habitats and wetlands, such as pans, dams and rivers. Primarily a scavenger, soaring overhead in search of carcasses. It is also an opportunistic hunter, catching fish. *Near-threatened* in South Africa, due its small population in the country

Species Name	P(Up)	Habitat Preference and Diet
Woolly-necked Stork *Ciconia episcopus*	55.20	Prefers flood plains, rivers, pans, ponds, dams, lagoons, swamp forests, mangrove swamps, tidal mudflats, estuaries and also man-made habitats, including golf courses, firebreaks and roads in plantations. Mainly eats insects and other invertebrates. *Near-threatened* in South Africa, due to low population numbers largely caused by habitat destruction
African Openbill *Anastomus lamelligerus*	72.61	Prefers wetlands, such as temporarily flooded pans, flood plains, swamps, marshes, ponds, streams, river shallows, dams, rice fields, lagoons, lake edges and intertidal flats. Almost exclusively eats snails and bivalves, as its bill is specially adapted to extract the meat without even breaking the shell
Hamerkop *Scopus umbretta*	18.40	Favours the shallow margins of lakes, pans, swamps, rivers, marshes, streams, seasonally flooded ponds and even small puddles in gravel roads. Eats mainly the adults and tadpoles of platanna frogs (*Xenopus)*, which have a very similar distribution to the Hamerkop, suggesting that it is dependent on them for food. It also eats other frogs, small fish and insects
Southern Ground Hornbill *Bucorvus leadbeateri*	13.81	Prefers grassland and savanna woodland habitats, ranging from montane grassland to extensive, tall stands of Zambezi teak *Baikiaea plurijaga*, Mopane *Colospermum mopane* and Musasa *Brachystegia spiciformis* woodlands with sparse understory. Mainly eats animals, such as insects, frogs, mongooses and bird nestlings. Listed as *Vulnerable* in South Africa. Its South African distribution has decreased vastly, due to persecution and habitat alteration. Its range is also decreasing in areas of Swaziland, Zimbabwe, Botswana and other areas of high human population density or extensive farming

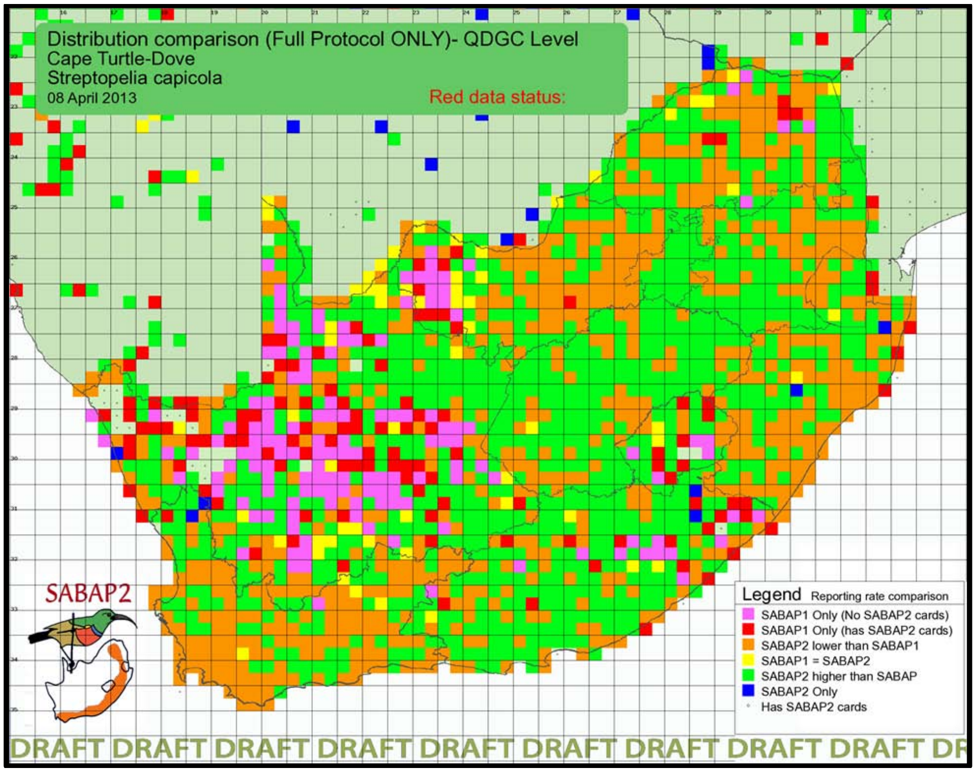

Figure 2.1 Distribution comparison map of Cape Turtle Dove in South Africa, Lesotho, and Swaziland, for SABAP1 and SABAP2

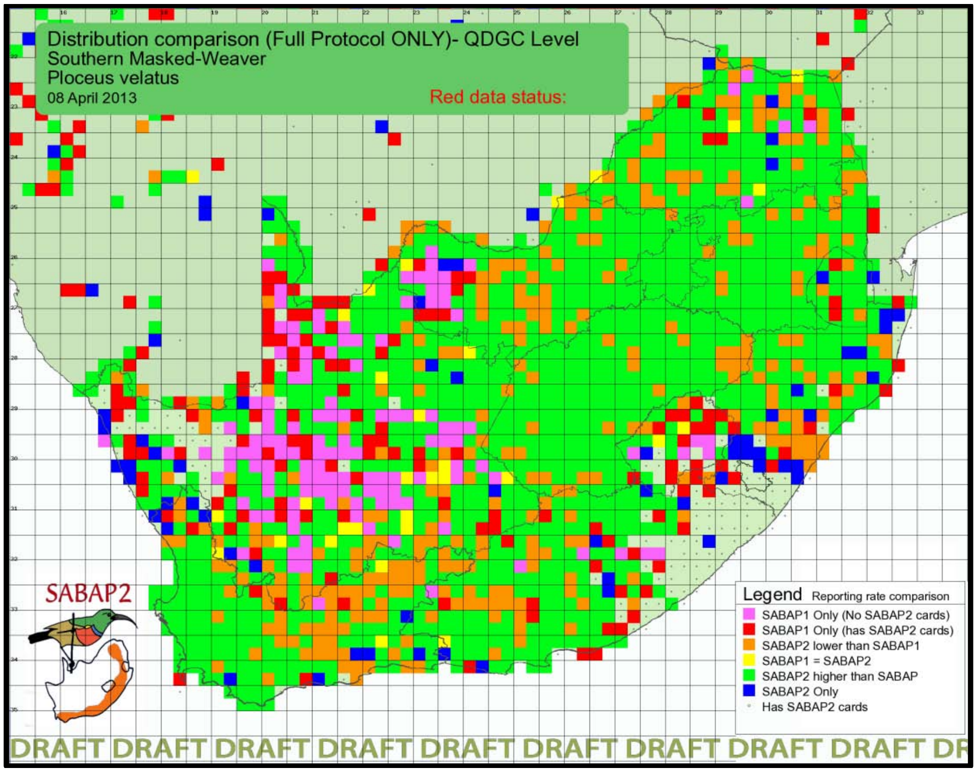

Figure 2.2 Distribution comparison map of Southern Masked Weaver in South Africa, Lesotho, and Swaziland, for SABAP1 and SABAP2

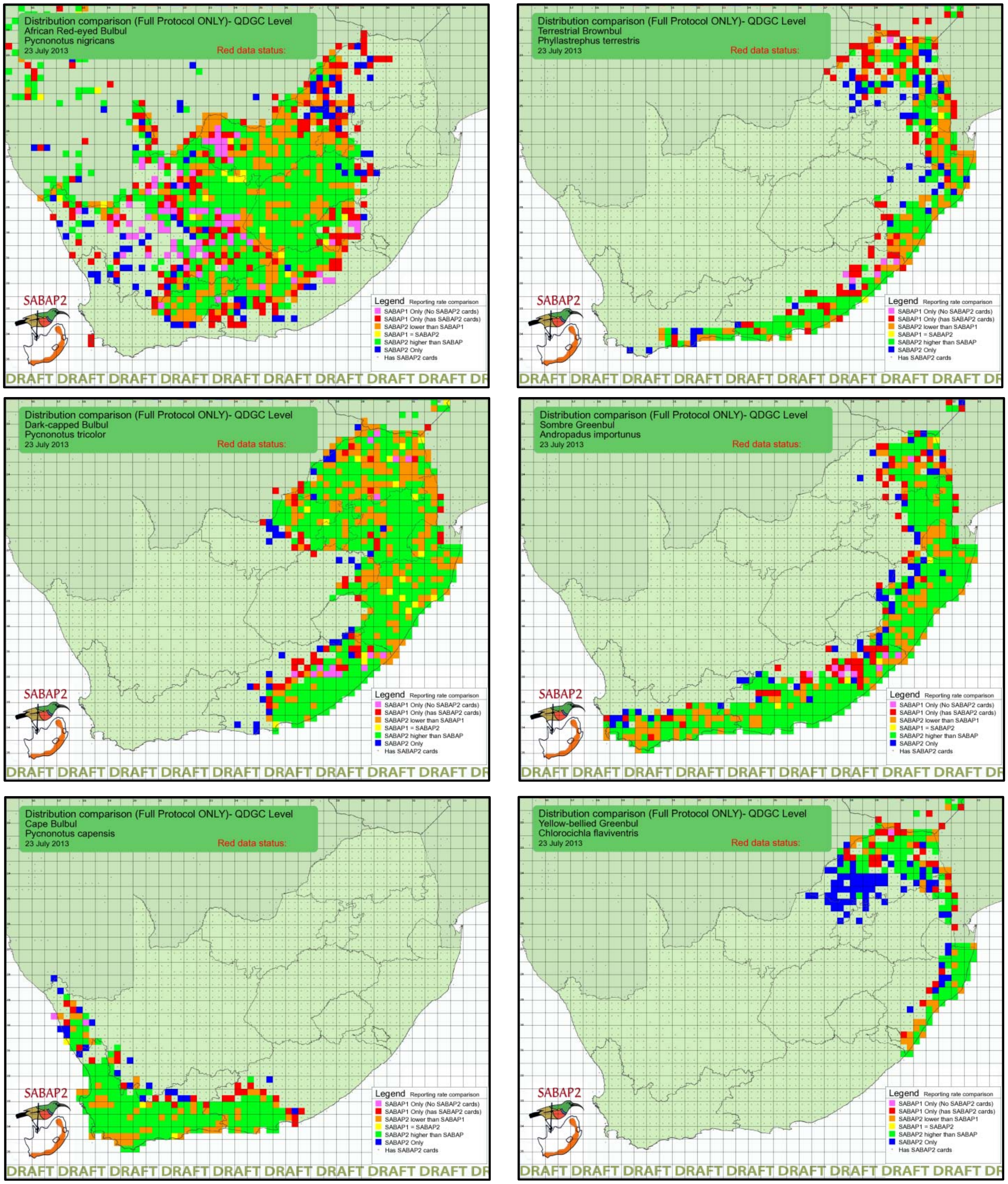

Figure 2.3 Pycnonotidae family range comparison maps between SABAP1 and SABAP2, arranged from smallest to largest percentage increase in reporting rate per QDGC

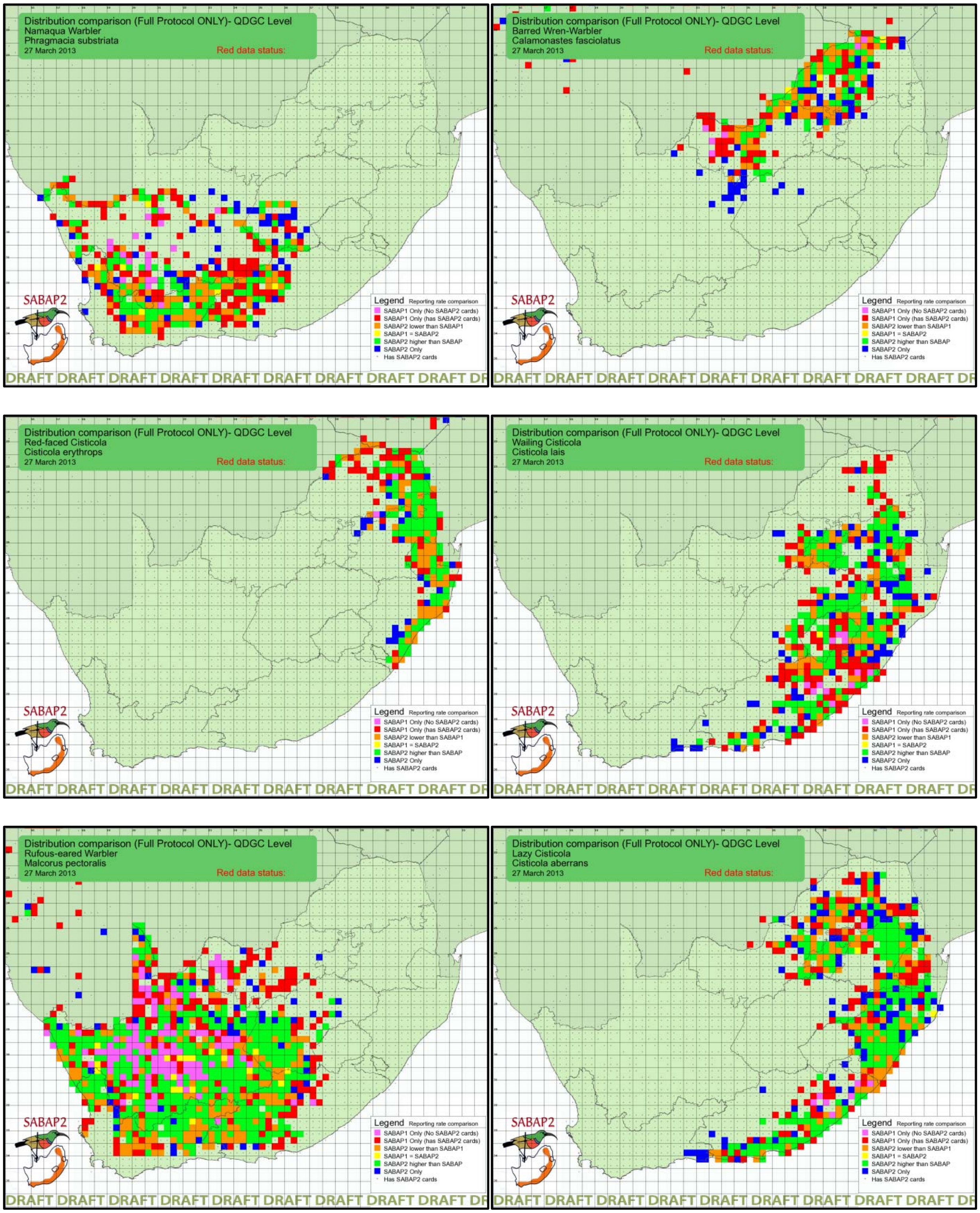

Figure 2.4 Cisticolidae family range comparison maps between SABAP1 and SABAP2, arranged from smallest to largest percentage increase in reporting rate per QDGC

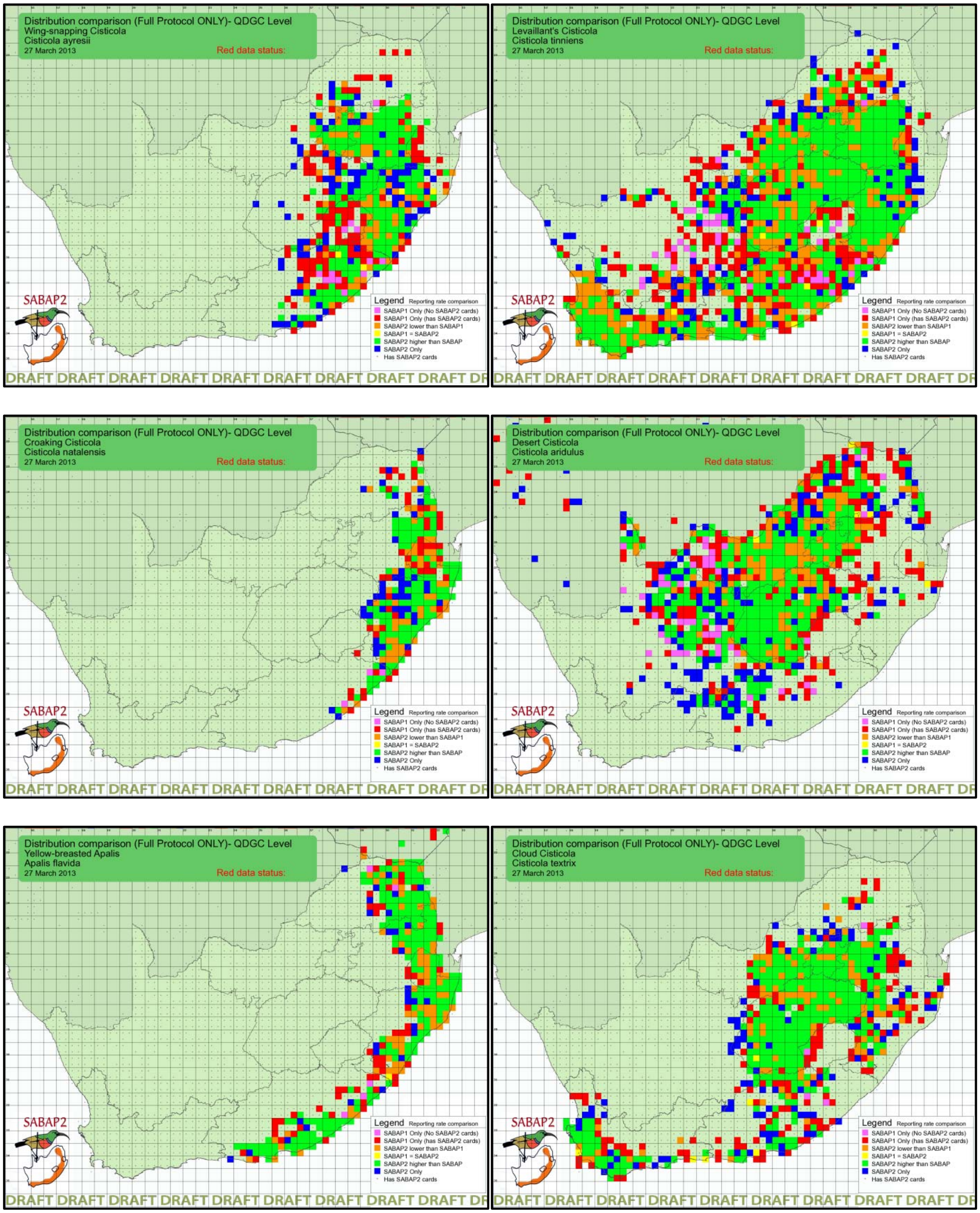

Figure 2.4 continued – Cisticolidae family range comparison maps between SABAP1 and SABAP2, arranged from smallest to largest percentage increase in reporting rate per QDGC

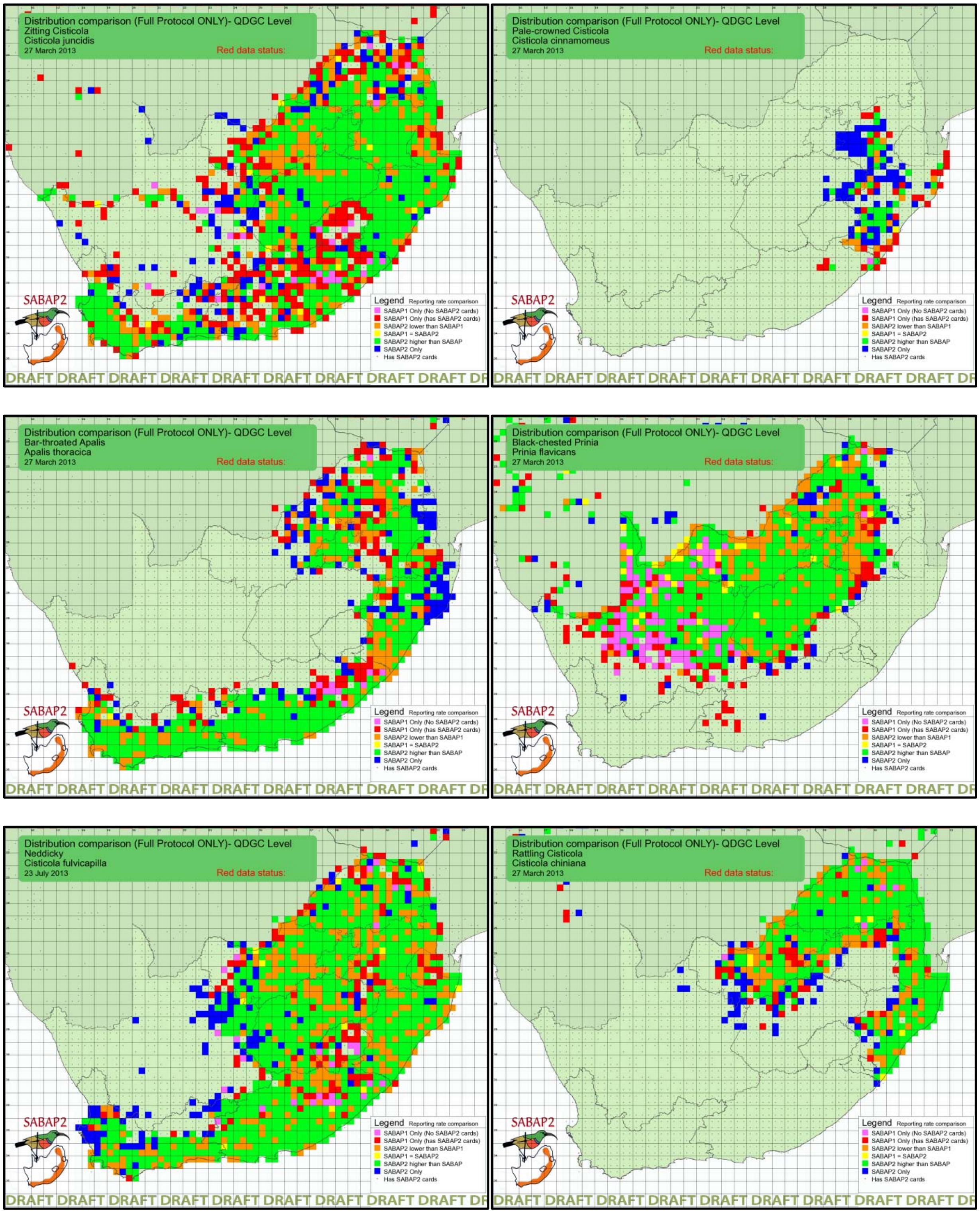

Figure 2.4 continued – Cisticolidae family range comparison maps between SABAP1 and SABAP2, arranged from smallest to largest percentage increase in reporting rate per QDGC

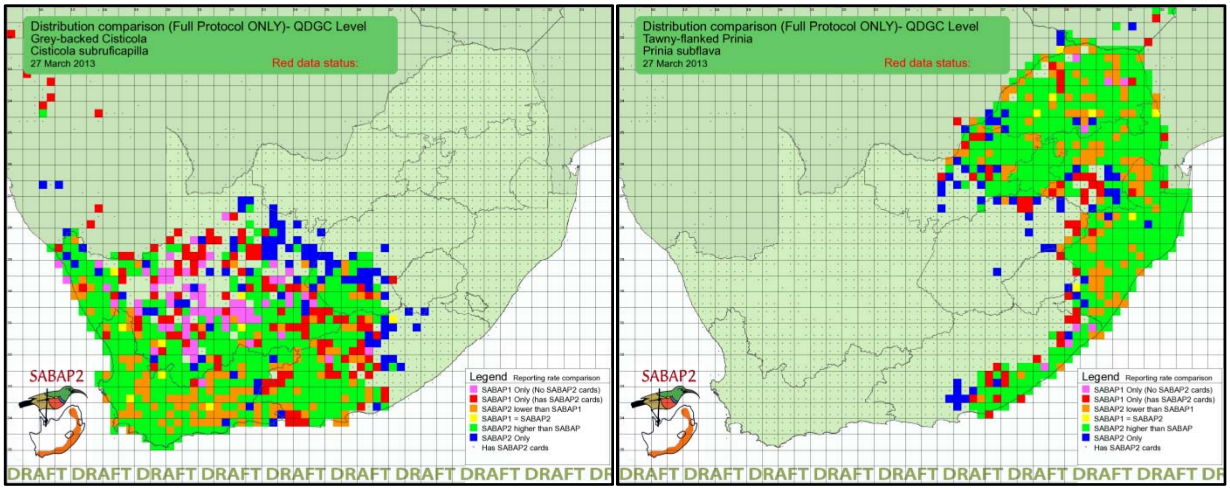

Figure 2.4 continued – Cisticolidae family range comparison maps between SABAP1 and SABAP2, arranged from smallest to largest percentage increase in reporting rate per QDGC

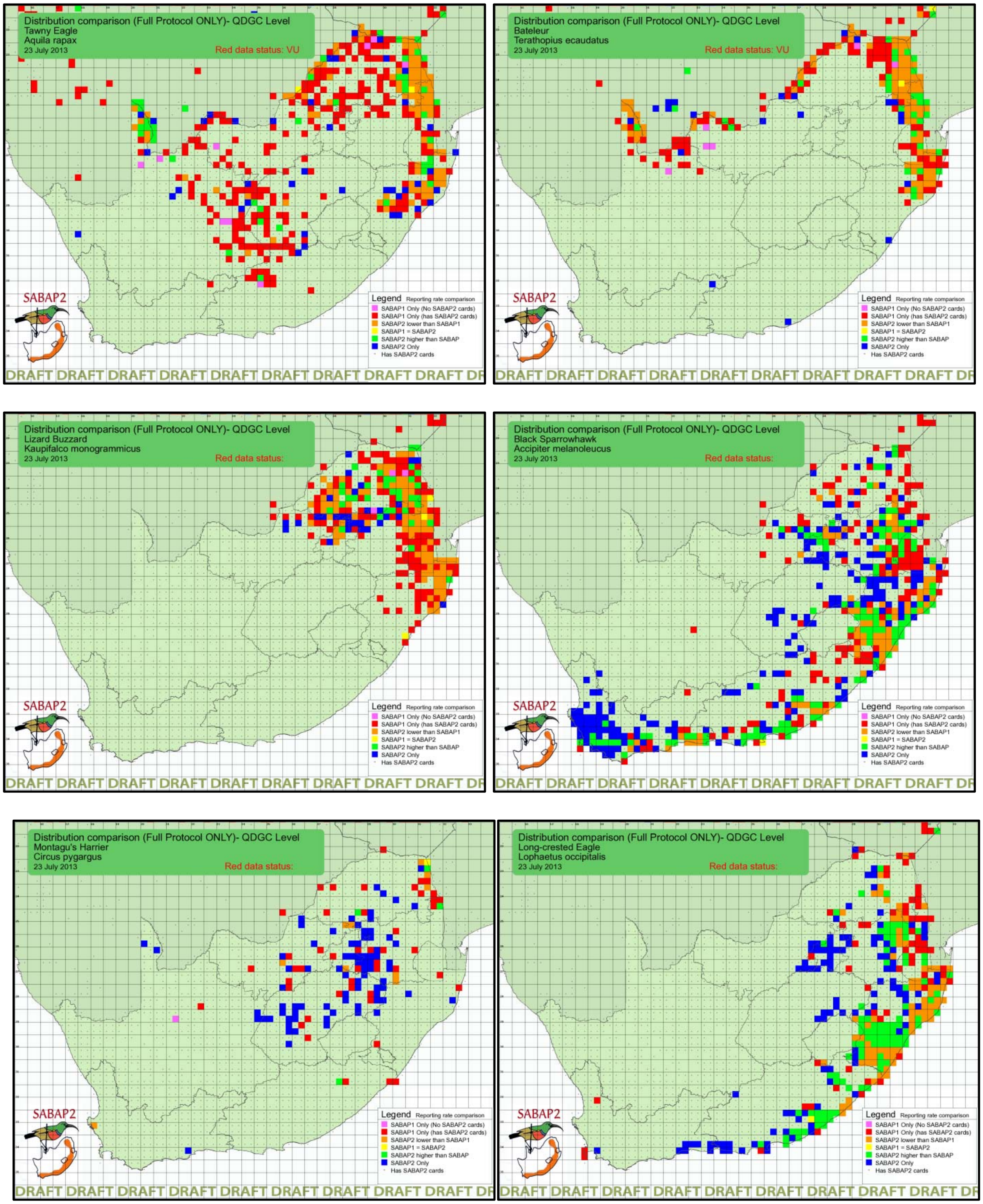

Figure 2.5 Accipitridae family range comparison maps between SABAP1 and SABAP2, arranged from smallest (bottom three maps) to largest (top three maps) percentage increase in reporting rate per QDGC

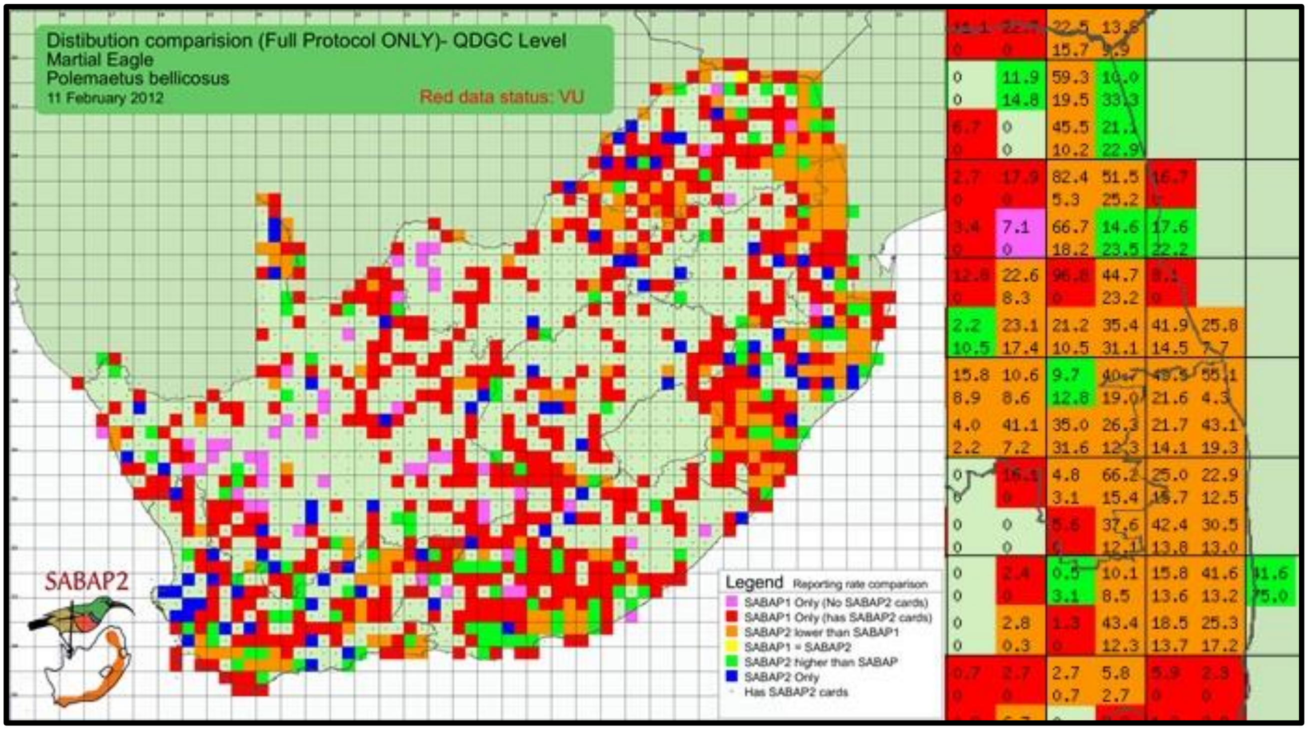

Figure 2.6 Range comparison map for Martial Eagle between SABAP1 and SABAP2 with insert of Kruger National Park area. The insert shows reporting rates (see text) for SABAP1 (top number in each quarter degree grid cell) and SABAP2 (bottom number in grid cell)

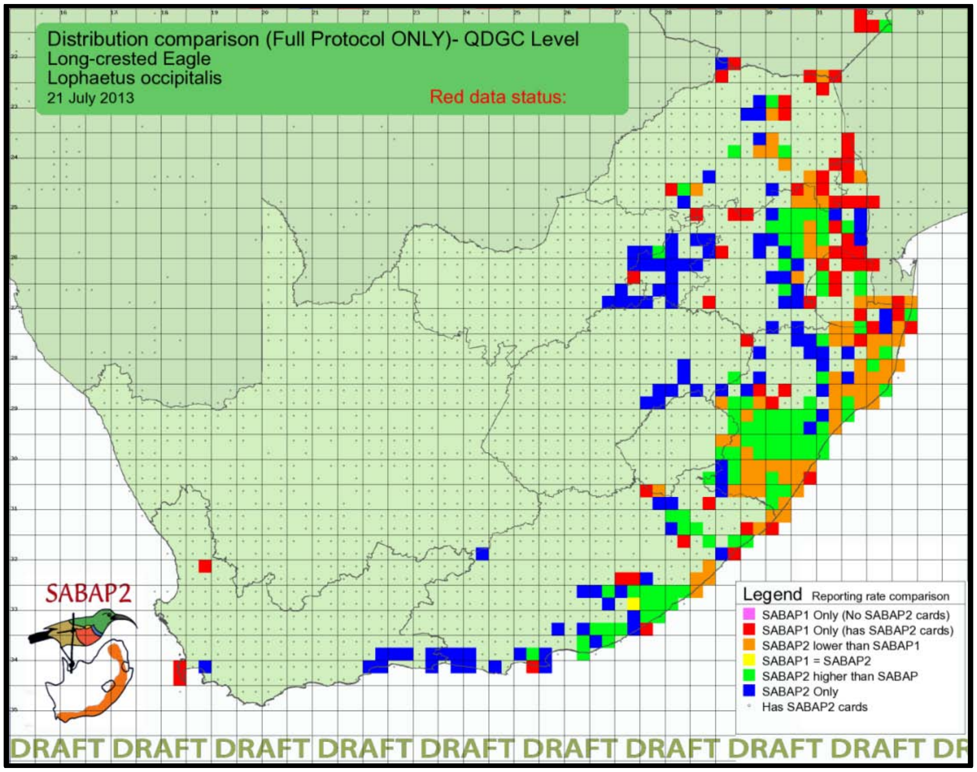

Figure 2.7 Range comparison map between SABAP1 and SABAP2 for Long-crested Eagle

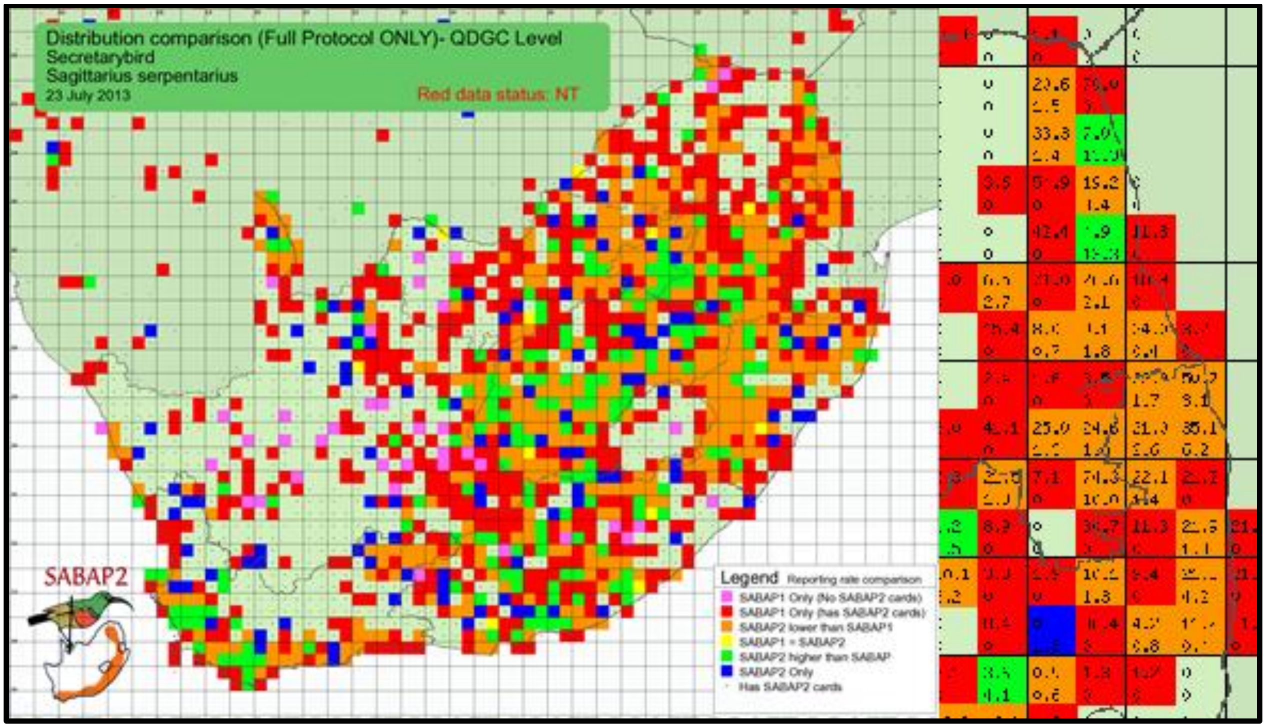

Figure 2.8 Range comparison map for Secretarybird between SABAP1 and SABAP2 with insert of Kruger National Park area. The insert shows reporting rates (see text) for SABAP1 (top number in each quarter degree grid cell) and SABAP2 (bottom number in grid cell)

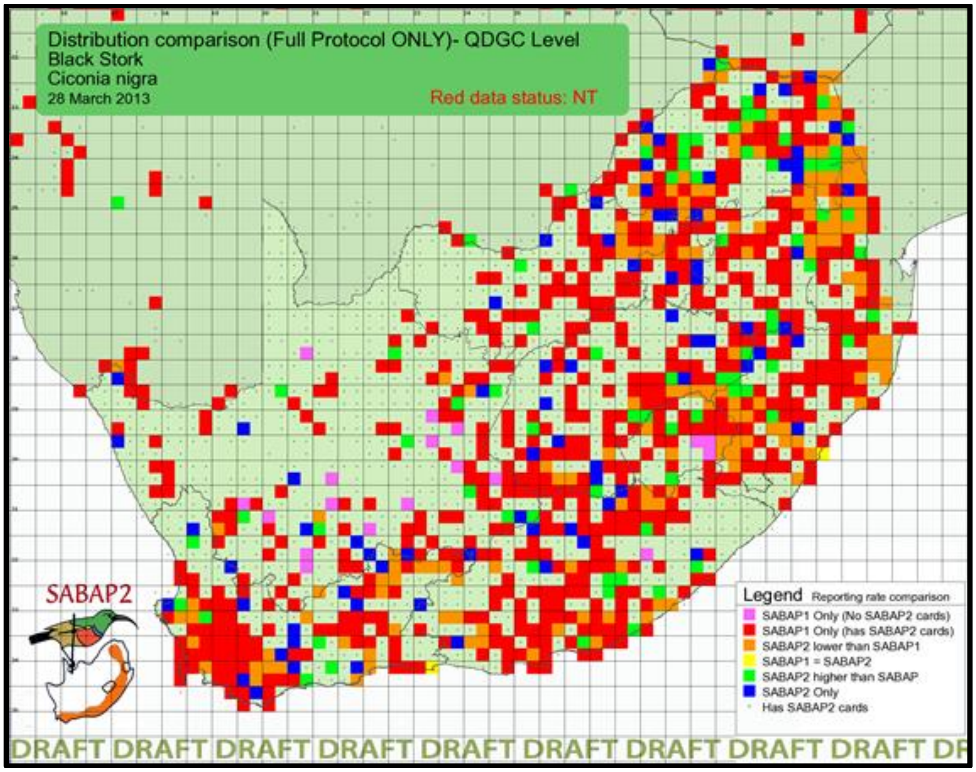

Figure 2.9 Range comparison map between SABAP1 and SABAP2 for Black Stork

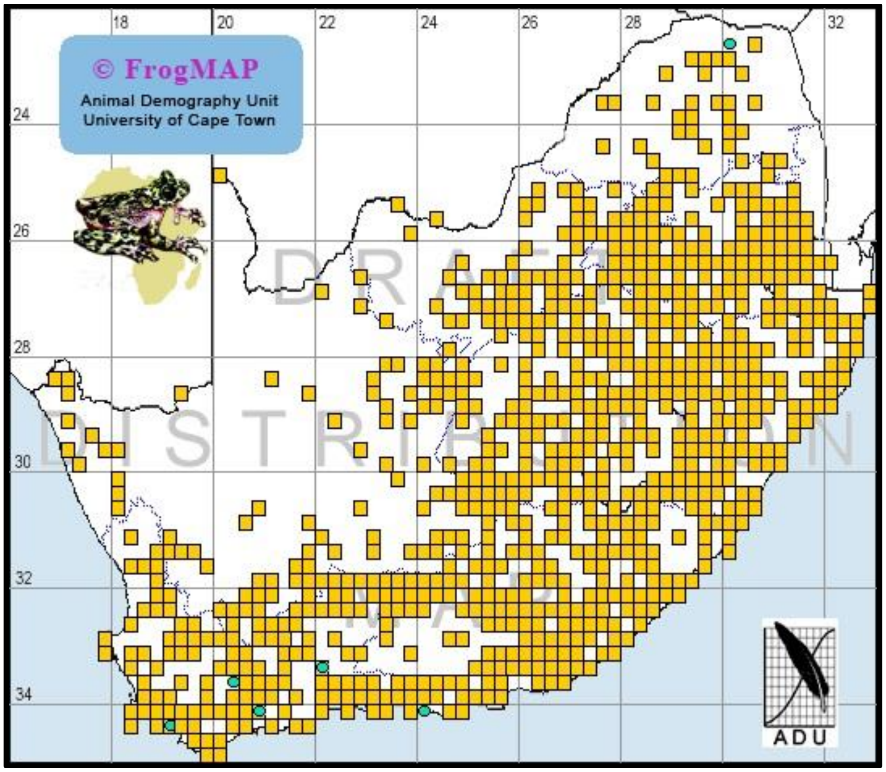

Figure 2.10 Distribution of Common Platanna *Xenopus laevis* in South Africa, Lesotho and Swaziland (map generated by the Animal Demography Unit's FrogMAP Virtual Museum, downloaded 29/07/2013; http://vmus.adu.org.za)

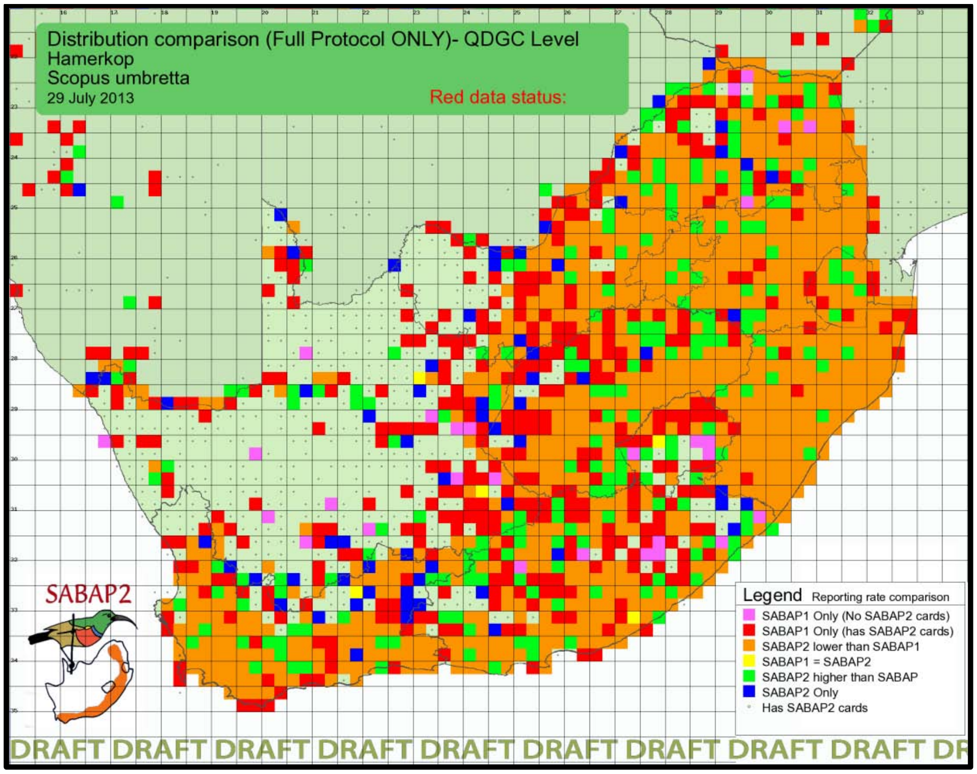

Figure 2.11 Range comparison map between SABAP1 and SABAP2 for Hamerkop

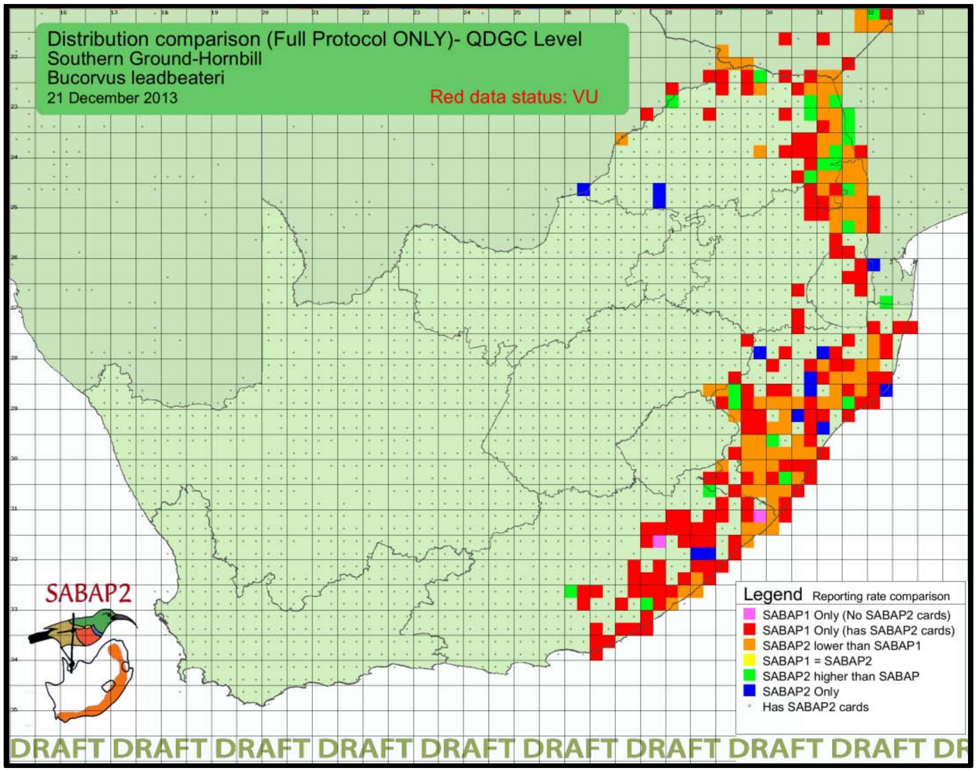

Figure 2.12 Range comparison map between SABAP1 and SABAP2 for Southern Ground Hornbill

CHAPTER 3

Changes in bird distributions between SABAP1 and SABAP2 in relation to other explanatory variables

Introduction

Birds vary in many aspects of their lives. Reproductive rate, age at maturity, diet, habitat preference and adult life span all differ radically between species. Taking a look at life-history characteristics of species should, in theory, provide a way of making predictive generalizations about species' responses in their geographic ranges because of environmental changes (Okes et al. 2008). However, not many studies have attempted to apply, or test the validity of this assumption across large numbers of related species. Although the direct causes of population and species loss have been studied widely, the problem of generalizing the reasons behind species declines or expansions remains a central scientific challenge (Okes et al. 2008). In order to make accurate predictions about future changes in biodiversity, it would be helpful if conservation biologists could develop an understanding of why and how certain species respond to habitat modification, both anthropogenic and natural, in different or similar ways in relation to readily available explanatory variables.

One approach, pioneered by Okes et al. (2008), which has potential, is to examine how the ranges and abundance of species have changed based on a framework of their life histories and ecological attributes in response to changes on the landscape over time. Previous studies conducted to investigate the reasons behind geographic range changes of birds in southern Africa had focused mainly on either habitat or climate change (Harrison 2000, Harebottle and Harrison 2001, Simmons et al. 2004). But these variables, alone, cannot necessarily be used to predict geographic range changes and species distributions without an accurate assessment of the life histories and habitat requirements of the species in question (Parmesan et al. 1999, Crick 2004).

Okes at al. (2008) tested the hypothesis that birds with similar life histories and/or ecological attributes respond in similar ways to environmental change. The study was carried out on 86 species of waterbirds. They argued that if the life-history approach as an explanatory variable for changes in species abundance and geographic range is useful, one would expect that range expansionists share life history and/or ecological attributes that differ from those of contractionists. The differences between range expansionists and range contractionists should shed light on the processes that drive changes in the ranges of birds in southern Africa (Okes et al. 2008). The life-history traits they examined included developmental mode (altricial, precocial), body mass, clutch size, nest dispersion (solitary, colonial), residency (extensive vs. limited movement), and diet (herbivorous, carnivorous, and insectivorous). Life history traits did contribute to a significant difference between expansionists and stable species (Okes et al. 2008). The most important variable contributing to this difference was movement. They showed that 76% of expansionists were capable of long-distance movement compared with only 37% of stable species (Okes et al. 2008). In terms of ecological traits, contractionists differed significantly from both expansionists and stable species. Expansionists clustered together on the basis of their use of pans and artificial wetlands for breeding and feeding (Okes et al. 2008).

In this chapter I discuss the changes in bird distributions between SABAP1 and SABAP2 in relation to explanatory variables other than family, which was the main focus of Chapter 2.

I take a look at various life history and ecological traits: diet, developmental mode, body mass, range size, habitat preference, mating system, endemism and Red Data status.

Methods

Data sources

As for Chapter 2, the study area was defined as the SABAP2 region, which consisted of South Africa, Lesotho and Swaziland. SABAP1 had also included Namibia, Botswana and Zimbabwe; the data for these countries were excluded from this analysis. The bird distribution and reporting rate data were extracted from the databases of SABAP1 and SABAP2 for 2007 quarter degree grid cells (QDGCs) in the study area. The full description of the data sources, and caveats related to their use, are provided in Chapter 2.

I used the same spreadsheet which summarized the life history information for every species in Hockey et al. (2005) as was used by Okes et al. (2008). (For the waterbirds, Okes et al. (2008) assembled some additional explanatory variables, such as dispersal distance for each species, which were therefore not available to this analysis.) This information was compiled from the species texts in Hockey et al. (2005) and where the information was not available it was left blank in this spreadsheet. Many of the columns in the spreadsheet were blank for most species (for example, survival rates) and these were therefore not used in the analysis. The primary usable components of the database, where there were limited numbers of missing values, included diet and habitat, and a selection of variables relating to breeding.

Threat status and Endemicity were coded as factor variables. Body mass was available for most species and was the only continuous variable extracted from the spreadsheet.

For the various categories of Diet and Habitat, the variables in the Okes et al. (2008) spreadsheet were coded with four levels (not used, occasional use, secondary diet or habitat, primary diet or habitat). The level "not used" was consistently used as the baseline level in the modelling. The 12 Diet categories were Carrion, Mammals, Birds, Reptiles, Fish, Other aquatic vertebrates, Terrestrial invertebrates, Marine invertebrates, Fruits, Seeds, Nectar, and Other plant parts (the names for the categories are as provided by the spreadsheet). I encountered a single error: the diet of Lizard Buzzard *Kaupifalco monogrammicus* was given as strictly mammals; I changed this to Mammals as secondary food source and to Reptiles as primary diet (Hockey et al. 2005). The habitat classification used consisted of 14 categories, with names as used in the spreadsheet: Cliffs, Forest, Woodland, Grassland, Savanna, Thicket, Fynbos, Karoo, Semi-arid rocky outcrops, Freshwater wetlands, Lagoons/estuaries and coastal wetlands, Open coast, Marine and Agricultural.

Statistical analysis

I used the same statistical approach as in Chapter 2, where full details are provided. The total number of QDGCs in which each species was recorded in either SABAP1 or SABAP2 was determined, and called the total range, denoted N_i. We considered only species which had a range of 100 or more QDGCs. The reporting rates for each species in both SABAP1 and SABAP2 were calculated, where the reporting rate is defined as the ratio of checklists recorded the species divided by the number of checklists for the QDGC. I calculated the number of QDGCs in which the reporting rate had increased between SABAP1 and SABAP2, and denoted this u_i.

I modelled u_i as a generalized linear model with a binomial distribution, $u_i \sim B(N_i, p_i)$. A full interpretation of the model is provided in Chapter 2. I modelled p_i as a function of explanatory variables through the logit transformation. In this chapter, a large series of explanatory variables derived from the spreadsheet of life history parameters discussed above.

I comprehensively explored the relationships between the explanatory variables which summarized the life history parameters and the number of QDGCs within the range which showed increased reporting rates.

A selection of the more interesting results, both those which were formally statistically significant and those that were not, are presented.

Results

As in Chapter 2, there were 1 399 QDGCs with four or more checklists for both projects. The number of species which had a range of 100 QDGCs or more and which were included in the generalized linear modelling was 514. They represented 79 families.

A large series of models, with various explanatory variables in many combinations, were fitted to the data to explore the relationships using the generalized linear model. For each model there were varying amounts of missing data, and each model used all species for which the data were available for every explanatory variable; thus the number of species included in each analysis varied (Table 3.1). As a first approach to evaluating each model, I used the percentage deviation explained as yardstick. Selected results are presented in Table 3.1.

Body mass was available for 509 of the 514 species (Table 3.1). Body mass, transformed to the logarithmic scale, accounted for 16.6% of the deviance in the generalized linear model for these 509 species. The regression coefficient was −0.133 ($t=-59.3$, $P<0.001$), indicating that as Body mass increased, there was, in general, a decrease in the number of QDGCs with increased reporting rates between the two atlas projects. The interpretation of this is that, on average, the smaller species have fared better than the larger species. However, when both Family and Body mass were included in the model, the percentage deviance explained was 46.6% (Table 3.1), the same as explained by Family alone (Chapter 2). The regression coefficient for the logarithm of Body mass in this model was 0.0016 (t=0.23, P=0.81) and was not significant. This suggests Body mass plays no explanatory role beyond than what is already explained by Family.

Using Range (and also its logarithm) as explanatory variable in the generalized linear model produced models which explained 1.3% and 1.4% of the deviance respectively (Table 3.1), indicating that, for species with a range of at least 100 QDGCs within the study region, Range itself was not a predictor of the direction of the change in the number of QDGCs with increased reporting rates. Likewise, Endemism (on a three point scale, Endemic, Near-endemic and Not endemic) accounted for 0.7% of the deviance. Threat status (of the 514 species, there were representatives of species classified as Vulnerable, Near-threatened and Least concern) accounted for 0.9% of the deviance (Table 3.1).

Of all the models considered in this chapter, Diet appeared to have the largest explanatory power, and is therefore presented in the greater detail than the other explanatory variables. Diet was expressed as 48 factor variables in the model, a baseline level for each of the 12 categories and three levels of increasing dependence (see Methods and Table 3.2). Diet accounted for 34.1% of the deviance (Table 3.1). Of the 12 Diet categories, the most important was Mammals: using the four levels of Mammals alone in the generalized linear model accounted for 15.5% of the deviance, more than for any other Diet category (Table 3.1) and the regression coefficients associated with the three levels for Mammals in the full Diet model with 48 factor variables had the largest t-values (Table 3.2). Where Mammals were classified as the “Main diet,” “Secondary food” and “Occasionally eaten” levels of a species, the estimates of the regression coefficients in relation to the baseline category “Not eaten” were −0.79 (t=−20.4, P<0.001), −1.00 (t=−22.4, P<0.001) and

−0.42 (t=19.7, P<0.001), respectively (Table 3.2). These were the largest t-values in Table 3.2, suggesting that of all the diet categories, Mammals are likely to have had the largest impact in explaining the number of grid cells with changed reporting rates. The regression coefficients are all negative, suggesting that, for species which feed on Mammals at any of the three levels, the direction of the change is towards decreases in reporting rates. For this reason this diet category is explored in more detail below. The analyses shown here for Mammals should also be undertaken for the other diet categories, using the approach for Mammals as a model.

Other interesting Diet categories are likely to be those with large values for the t-statistic in Table 3.2. Species which have Birds as "main diet" appear to have shown an increase (t=12.6, P<0.001). Species which have Terrestrial Invertebrates at any of the three diet dependency levels also appear to have shown an increase (Main diet regression coefficient 0.19, t=10.1, P<0.001; Secondary food coefficient 0.10, t=4.7, P<0.001; Occasionally eaten coefficient 0.16, t=8.7, P<0.001). Species which are "Occasional" Nectar feeders have increased (regression coefficient 0.27, t=19.5, P<0.001). Species which were classified as having Freshwater Invertebrates as main diet have decreased (regression coefficient −0.24, t=−10.5, P<0.001) and the same applies to species with Marine Invertebrates as main diet (regression coefficient −0.54, t=−15.0, P<0.001) (Table 3.2).

Habitat explained 19.4% of the deviance in the generalized linear model (Table 3.1). Habitat was modelled using 55 factor variables, four levels for each of the 14 Habitat categories recognized in the spreadsheet; no species were classified as being Marine as a secondary Habitat level, so there were 55 variables in total (Table 3.3). The patterns of pluses and minuses for the regression coefficients within Habitat categories in Table 3.3 are less consistent than they were for the Diet categories of Table 3.2, suggesting the possibility that this analysis is sensitive to the effects of small sample sizes of membership in some levels of Habitat categories. But five Habitat categories had consistent and significant signs for their levels: Cliff, Woodland, Thicket, Lagoon and estuary, and Agriculture (Table 3.3). Species with habitat dependencies on Cliffs and Lagoon and estuary showed decreases; in contrast, species with habitat dependencies on Woodland, Thicket and Agriculture showed increases (Table 3.3).

Of the available explanatory variables related to breeding, the only one that appeared to be interesting was Developmental mode. This was classified to four levels: Altricial (used as the baseline); there were 345 species in this level; Semi-altricial, 61 species; Semi-precocial, 7 species; and Precocial, 59 species. Developmental mode was thus available for 472 species, a relatively large proportion of the 514 species. Developmental mode accounted for 14.8% of the deviance in the generalized linear model (Table 3.1). In relation to the baseline category of Altricial breeding, the other regression coefficients were negative (Semi-altricial −0.58, $t=-48.8$, $P<0.001$; Semi-precocial −0.18, $t=-3.85$, $P<0.001$; Precocial −0.27, $t=-23.3$, $P<0.001$).

I continue with a more in-depth analysis of the results relating to what appears to be the most important explanatory variable considered in this chapter, a diet consisting of Mammals. We examine more closely the species which were classified as having mammals as either the main diet or the secondary diet. Of the 14 species that were classified as feeding mainly on mammals, the African Grass Owl *Tyto capensis* (Figure 3.1) had the smallest probability of a QDGC displaying increased reporting rates at 17.1% (Table 3.4). The median rate for the 14 species was 30.0%. 11 species had probabilities between 17.1% and 34.5%, with the Black-headed Heron in 11th position (Table 3.4). The remaining three species of the 14 seemed to defy the overall pattern: Long-crested Eagle at 62.2%, Southern Pale Chanting Goshawk *Melierax canorus* at 52.3% and Jackal Buzzard *Buteo rufofuscus* at 46.0% (Table 3.4).

Of the 13 species that were classified as feeding on mammals as a secondary food, the Tawny Eagle *Aquila rapax* had the smallest probability of increased reporting rate at 18.7% (Table 3.5). The median was 28.1%. There appeared to be one outlier in this group: the White-necked Raven *Corvus albicollis* had the largest probability of increased reporting rates in QDGCs, at 56.0% (Table 3.5).

Discussion

The most important outcome of this analysis is that, in the context of the databases generated by the two bird atlas projects in southern Africa, SABAP1 and SABAP2, there is clearly a rich array of relationships between changes in bird distributions over two decades and these explanatory variables associated with life histories. This chapter has only scratched the surface of the potential for discovering these relationships. The statistical approach used in this chapter (as in Chapter 2) was exploratory, and simply counted the number of QDGCs within the range of a species at which the reporting rates had increased in relation to the total range. Some small protection against these changes in reporting rate being attributable to sampling error was obtained by restricting the analysis to QDGCs with at least four checklists for both projects. However, in spite of the limitations of these analyses, it is abundantly clear that these databases are robust enough to demonstrate that more in depth analyses are worth pursuing.

Another important outcome of the analyses in this chapter and in Chapter 2 is that the distributions of many bird species in the study area are changing, and that these changes are not random, but are patterned and shaped by changes to the environment. It is also clear that the magnitudes of the changes are, in general, sufficiently large to be detectable and at least partially explained by fairly unsophisticated statistical approaches.

A third outcome of these analyses is that the results of the two bird atlas projects in southern Africa have huge conservation implications. The insights provided by an understanding of the changes in bird distribution in relation to environmental variables and life history parameters have the potential to guide bird conservation interventions in this region in the coming decades.

One such insight, which is unlikely to have been predicted *a priori* is that, with some striking exceptions, species which include mammals in their diet are in decline (Tables 3.1, 3.4 and 3.5).

The vast majority of the 27 species listed in the file described by Okes et al. (2008) as having mammals as the main or secondary diet showed large percentages of QDGCs with decreased reporting rates (Table 3.4 and 3.5). Only two of the 27 species can be described as largely scavengers: Tawny Eagle and Bateleur *Terathopius ecaudatus*. The remaining species, although they do opportunistically take carrion, mostly actively hunt for live prey. Examining the summarized descriptions of diet in Tables 3.4 and 3.5, and the fuller descriptions in Hockey et al. (2005), it is apparent that small mammals and micro-mammals (and especially rodents) form a large component of their diet.

Those bird species which rely on these rodents as a large component of their diet are likely to be vulnerable to the population cycles of these rodents. Rodent population outbreaks in Africa seem to occur primarily in species belonging to the murine genera *Mastomys* (multimammate mice) and *Arvicanthis* (grass mice) (Wilson and Reeder 2005). Both genera are endemic to Africa. *Mastomys* is the most abundant genus of rodents (and probably of mammals) in Africa, and currently comprises eight species (Wilson and Reeder 2005). It is widespread south of the Sahara Desert in Africa. A very important factor in their outbreak capacity is their considerable reproductive potential, which is characterized by the large number of mammae (8–12 pairs) that these mice have; hence, their common name of multi-mammate mice. Under good environmental conditions, litter sizes can reach 27 young (Duplantier et al. 1996) with potential reproductive capacity rates of up to 68 young per adult female (Leirs et al. 1993). Importantly, changes in population numbers of African rodents seem to be regulated mainly by processes that influence primary production (Leirs et al. 1993). It is hypothesized that one of the main causes of multimammate mice population outbreaks is an abundant amount of rainfall, particularly early or late in the season, which is essential for stimulating primary production (Leirs et al. 1993). Thus climate change can potentially have an influence on the frequency of rodent outbreaks with knock-on effects onto all those species that depend on them in the food chain.

The multimammate mouse *Mastomys natalensis* is known to exhibit periodic population explosions. A number of authors (Vernon 1972, Dean 1973, Mendelsohn 1989, Wirminghaus 1989) have reported that when and where *M. natalensis* was abundant, it became the staple food source for the Barn Owl *Tyto alba*. In Zimbabwe, *M. natalensis* dominated the diet of the African Grass Owl but was absent from that of the Marsh Owl *Asio capensis* (Armstrong 1991). The African Grass Owl often occurs in the long grass on moist soils of drainage lines, and analysis of prey taken suggests that the small mammals (rodents) of the vleis/marshes are important in its diet (Dean 1990).

Malherbe (1963) found that during a rodent plague, comprised mostly of multimammate mice, there was a significant increase in the raptor population at Boshoek, 22.5 km north of Rustenburg, North West Province, and many of these raptors were breeding much earlier than usual for this particular area. Barn Owls, Marsh Owls and Black-shouldered Kites *Elanus axillaris* were attracted to the area because of the large rodent population (Malherbe 1963). This suggests that many of the birds that rely on mammals, and especially rodents, as part of their diet can be vulnerable to the boom-bust cycles typically shown by small mammal populations. It is likely that successful breeding attempts take place mainly in the years of rodent plagues. Interruption of these plague cycles, whether attributable to land-use transformation, pest eradication campaigns or climate change, or a combination of these factors, may be playing a substantial role in the decreases of bird species dependent, to a greater or lesser extent, on mammals.

This statistical analysis, a desk top study, suggests that a key bird conservation issue relates to fairly universal declines in bird species with a diet that contains mammals. This result needs to be confirmed by an in depth field study on these species. What will be required is a study of population trends of mammals, and a study of the frequency of occurrence of rodent plagues.

Those bird species which were classified as occasional and secondary nectar feeders had positive regression coefficients in Table 3.1. These species include many of the Pycnonotidae, and Ploceidae, families shown in Chapter 2 to be increasing. These are the three families that have demonstrated the largest increases in reporting rates.

Among the other results reported in Table 3.1, it was unexpected how many seemingly important variables had small explanatory power. This was particularly true of Range size, Endemism status and Threat status. However, the analysis reported here was restricted to species that occurred in 100 or more QDGCs. Additional analyses (not shown) demonstrated that including more species by having a less severe restriction on number of QDGCs did not change the results substantively. These results are so radical that they need to be pursued more rigorously and with alternative statistical approaches. If they are indeed demonstrated to be correct, then the traditional yardsticks driving conservation imperatives are turned upside down by these results.

All the breeding-related explanatory variables, except one, had small explanatory power (Table 3.1). The exception was Developmental mode, which accounted for 14.8% of the deviance (Table 3.1). Species with altricial breeding systems were more likely to be increasing their reporting rates than the remaining three categories. This result is consistent with the general process of bush thickening taking place across the study area (Chapter 2). Many species which have altricial breeding systems build their nests in trees and shrubs, and a general thickening of bush would assist in concealing both the nest itself and the movement of adults towards nests which is the cue used by many predators to locate altricial nests.

Conclusions

The patterns of changes of bird distributions in the study area are not random, but are clearly linked to a series of explanatory variables. Unfortunately, the database of life histories upon which this study is based is incomplete for many interesting and important variables, so that the impact of these on changing patterns of bird distribution could not be examined. It would be valuable to keep this database updated as new life history information becomes available for species.

Survival rate, age at first breeding and dispersal distance (the variable found by Okes et al. (2008) to be the most important) seem to be key explanatory variables that ought to be examined.

One category of explanatory variable for which no data are available could be labelled as "Threats." For example, a factor variable giving, for each species, a rating on a four-point scale to vulnerability to transmission line collisions would help evaluate whether changes in distribution appear attributable to this threat. Similar explanatory variables could be developed for sensitivity to human disturbance, sensitivity to afforestation, sensitivity to poisoning, sensitivity to loss of wetland habitat, etc. (Barnes 2000). With a comprehensive series of threat variables, it should be possible to examine which is the most important in terms of actual measurable changes in distribution.

Nevertheless, this chapter demonstrates that, for the life history variables for which information is available for large numbers of species, explanatory relationships do exist. This is encouraging in its own right, and provides justification for the huge amount of effort devoted by "citizen scientists" into the two bird atlas projects (SABAP1 and SABAP2). These are undoubtedly the most important bird conservation initiatives that have taken place in southern Africa.

Table 3.1 Percentage of deviance explained in model according to various explanatory variables

Explanatory variable included in model:	Percentage (%) of the deviance explained by explanatory variable:	Number of species
Log body mass	16.6	509
Family + Log body mass	46.6	509
Range size	1.3	514
Log Range size	1.4	514
Endemism	0.7	514
Threat Status	0.9	514
Diet	34.1	501
Diet + Log body mass	35.3	496
Diet(Mammals)	15.5	513
Diet(Freshwater Invertebrates)	9.7	513
Diet(Nectar)	7.8	510
Diet(Terrestrial invertebrates)	6.4	512
Diet (Carrion)	5.5	509
Diet (Seeds)	2.7	514
Diet (Birds)	10.2	512
Diet (Reptiles)	11.0	512
Diet (Marine invertebrates)	5.5	513
Diet (Other plant parts)	1.0	511
Habitat type	19.4	514
Habitat type + Log body mass	28.7	508
Mating System	0.7	455
Nest dispersion	0.7	409
Territoriality	1.0	342
Nest site	4.6	327
Male display	1.6	209
Incubation period	0.1	235
Developmental mode	14.8	472
Nestling period	0.0	162
Nest building	6.9	162
Incubation type	1.1	227

Table 3.2 Results of the generalized linear model with Diet as explanatory variable. Each of the Diet categories had four levels (the baseline level in each category for the model was "Not eaten", levels 1, 2 and 3 were "Occasionally eaten", "Secondary food" and "Main diet" respectively). The regression coefficients in each diet category are therefore in relation to "Not eaten"

Parameter	Estimate of regression coefficient	s.e.	t	P
Constant	–0.0904	0.0195	–4.63	<.001
Carrion 1	–0.1536	0.0187	–8.22	<.001
Carrion 2	0.7587	0.0439	17.29	<.001
Carrion 3	–0.4789	0.0609	–7.87	<.001
Mammal 1	–0.4202	0.0213	–19.69	<.001
Mammal 2	–0.9964	0.0445	–22.41	<.001
Mammal 3	–0.7861	0.0385	–20.41	<.001
Bird 1	0.0028	0.0175	0.16	0.875
Bird 2	0.1237	0.0418	2.96	0.003
Bird 3	0.4074	0.0324	12.58	<.001
Reptile 1	–0.1103	0.0175	–6.29	<.001
Reptile 2	–0.0647	0.0334	–1.94	0.053
Reptile 3	–0.0454	0.0377	–1.20	0.229
Fish 1	–0.1254	0.0189	–6.64	<.001
Fish 2	–0.2170	0.046	–4.72	<.001
Fish 3	–0.1396	0.0279	–5.00	<.001
Other aquatic 1	0.0024	0.0170	0.14	0.888
Other aquatic 2	–0.0072	0.0438	–0.17	0.869
Other aquatic 3	–0.0803	0.0317	–2.53	0.011
Terrestrial Invertebrates 1	0.1644	0.019	8.66	<.001

Parameter	Estimate of regression coefficient	s.e.	t	P
Terrestrial Invertebrates 2	0.1033	0.0218	4.74	<.001
Terrestrial Invertebrates 3	0.1905	0.0188	10.11	<.001
Fresh Water Invertebrates 1	–0.0111	0.0196	–0.57	0.571
Fresh Water Invertebrates 2	0.0774	0.0297	2.61	0.009
Fresh Water Invertebrates 3	–0.2413	0.0231	–10.45	<.001
Marine Invertebrates 1	–0.1003	0.0229	–4.38	<.001
Marine Invertebrates 2	–0.2071	0.0727	–2.85	0.004
Marine Invertebrates 3	–0.5401	0.0361	–14.96	<.001
Fruits 1	0.0443	0.012	3.68	<.001
Fruits 2	0.0047	0.0202	0.23	0.816
Fruits 3	–0.0153	0.0195	–0.78	0.433
Seeds 1	–0.0578	0.0138	–4.20	<.001
Seeds 2	0.0184	0.0218	0.85	0.398
Seeds 3	0.0221	0.0134	1.65	0.099
Nectar 1	0.2675	0.0138	19.45	<.001
Nectar 2	0.6531	0.0853	7.66	<.001
Nectar 3	–0.0517	0.0286	–1.81	0.07
Other plant parts 1	–0.0470	0.0147	–3.19	0.001
Other plant parts 2	–0.0774	0.0217	–3.57	<.001

Parameter	**Estimate of regression coefficient**	**s.e.**	**t**	**P**
Other plant parts 3	–0.2746	0.0310	–8.85	<.001

Table 3.3 Results of the generalized linear model with Habitat as explanatory variable. Each of the Habitat categories had four levels (the baseline level in each category for the model was "Not used", levels 1, 2 and 3 were "Occasionally used", "Secondary habitat" and "Main habitat" respectively). The regression coefficients in each diet category are therefore in relation to "Not used"

Parameter	Estimate of regression coefficient	s.e.	t(*)	t pr.
Constant	–0.2744	0.0163	–16.80	<.001
Cliff 1	–0.0670	0.0306	–2.19	0.028
Cliff 2	–0.6181	0.0336	–18.42	<.001
Cliff 3	–0.3022	0.0223	–13.52	<.001
Forest 1	–0.0591	0.0153	–3.87	<.001
Forest 2	–0.0719	0.0277	–2.59	0.009
Forest 3	0.0828	0.0218	3.8	<.001
Woodland 1	0.1244	0.0141	8.83	<.001
Woodland 2	0.1562	0.0164	9.5	<.001
Woodland 3	0.1709	0.0154	11.12	<.001
Grassland 1	0.0095	0.0125	0.76	0.448
Grassland 2	–0.1974	0.0199	–9.93	<.001
Grassland 3	–0.0148	0.0129	–1.14	0.253
Savanna 1	0.1751	0.0143	12.27	<.001
Savanna 2	–0.0598	0.0181	–3.30	<.001
Savanna 3	0.0491	0.0149	3.29	0.001
Thicket 1	0.2133	0.0142	15.05	<.001
Thicket 2	0.0862	0.05	1.73	0.084
Thicket 3	0.4458	0.0474	9.42	<.001
Fynbos 1	–0.0048	0.0139	–0.34	0.732
Fynbos 2	0.1109	0.0233	4.75	<.001
Fynbos 3	0.013	0.0215	0.61	0.544
Karoo 1	–0.0623	0.0137	–4.56	<.001

Parameter	**Estimate of regression coefficient**	**s.e.**	**t(*)**	**t pr.**
Karoo 2	–0.1212	0.0199	–6.09	<.001
Karoo 3	0.1072	0.0178	6.01	<.001
Rocky outcrop 1	0.0797	0.0169	4.71	<.001
Rocky outcrop 2	–0.4424	0.0468	–9.45	<.001
Rocky outcrop 3	0.1191	0.0216	5.52	<.001
Wetland 1	–0.0969	0.0189	–5.12	<.001
Wetland 2	0.4286	0.0261	16.4	<.001
Wetland 3	0.167	0.015	11.1	<.001
Lagoon 1	–0.0178	0.0169	–1.05	0.293
Lagoon 2	–0.3494	0.0231	–15.13	<.001
Lagoon 3	–0.5295	0.0277	–19.09	<.001
Open coast 1	–0.0567	0.0168	–3.37	<.001
Open coast 2	0.0461	0.0541	0.85	0.394
Open coast 3	0.2051	0.0383	5.36	<.001
Marine 1	–0.2733	0.0565	–4.84	<.001
Marine 3	0.04	0.131	0.31	0.76
Agricultural 1	0.0521	0.0119	4.39	<.001
Agricultural 2	0.0725	0.0137	5.3	<.001
Agricultural 3	0.2178	0.0156	13.93	<.001

Table 3.4 Bird species whose main diet consists of mammals, arranged from smallest to largest proportion of QDGCs showing an increase in reporting rate. Notes on diet summarized from Hockey et al. (2005)

Species Name	P(Up)	Notes on Diet
African Grass Owl *Tyto capensis*	17.12	Mainly eats rodents. *Vulnerable* in South Africa, largely caused by habitat degradation through ploughing, grazing, draining and burning; its population in the country is thought to be less than 5000 individuals
Cape Eagle Owl *Bubo capensis*	20.08	Mainly eats mammals, supplemented with birds, reptiles and invertebrates. Not threatened, but potentially impacted by overgrazing and fires.
Black-shouldered Kite *Elanus caeruleus*	26.02	It mainly eats rodents, but also insects and lizards.
Marsh Owl *Asio capensis*	26.17	Eats rodents, bats and shrews as well as insects, birds and reptiles.
Verreaux's Eagle *Aquila verreauxii*	27.83	It mainly eats mammals, especially rock hyraxes, doing most of its hunting from a perch, from which it descends to pluck prey from the ground.
Verreaux's Eagle Owl *Bubo lacteus*	28.10	Diet consists of a wide variety of animals, most of which are vertebrates such as mammals (vervet monkeys, bats, mongooses) and birds.
African Crowned Eagle *Stephanoaetus coronatus*	30.60	It mainly eats mammals (especially hyraxes and antelope). *Near-threatened* in South Africa, largely due to persecution by small stock farmers.
Black Harrier *Circus maurus*	31.37	It mainly eats mice and birds. Globally *Vulnerable*, *Endangered* in Namibia and *Near-threatened* in South Africa. Outside of protected areas it is largely reliant on the remnants of natural vegetation in agricultural land.
African Marsh Harrier *Circus ranivorus*	32.77	Mainly eats small mammals. *Endangered* in Namibia and *Vulnerable* in South Africa, as there has been an estimated 20% population loss due to wetland loss and fires during the breeding season.
Barn Owl *Tyto alba*	33.44	Usually, its diet consists of 75 - 97% rodents, with the rest largely made up of shrews and small birds. In urban areas, however, small birds dominate its diet, making up 40 - 95% of prey items. Their population does vary year to year due to the availability of food, especially rodents.
Black-headed Heron *Ardea melanocephala*	34.51	Mainly eats terrestrial insects, supplemented with small mammals, reptiles and birds. Benefits from habitat disturbance and agriculture.

Species Name	**P(Up)**	**Notes on Diet**
Jackal Buzzard *Buteo rufofuscus*	45.98	Mainly eats mammals, supplemented with birds and lizards, doing most of its hunting from high up in the air or from a perch. Scavenges at carcasses, especially in Winter when food is scarce.
Southern Pale Chanting Goshawk *Melierax canorus*	52.23	It mainly eats mammals (hares and rodents). Also reptiles, carrion and birds.
Long-crested Eagle *Lophaetus occipitalis*	62.15	Mainly eats rodents, but also birds, frogs and reptiles.

Table 3.5 Bird species whose diet secondarily consists of mammals, arranged from smallest to largest percentage of QDGCs showing increases in reporting rates. Notes on diet summarized from Hockey et al. (2005)

Species Name	P(Up)	Notes on Diet
Tawny Eagle *Aquila rapax*	18.66	Predator, pirate and scavenger, feeding on a wide variety of animals.
Bateleur *Terathopius ecaudatus*	21.80	Mainly a scavenger, although about a third of its time is spent hunting, feeding on a variety of animals. Falls victim to persecution as well as dying from poisoned bait put out for jackals.
Rock Kestrel *Falco rupicolus*	22.88	Mainly eats small birds, lizards, mammals and arthropods.
Lizard Buzzard Kaupifalco monogrammicus	24.07	Mainly eats lizards, snakes, frogs and rodents, doing most of its hunting from a perch over long grass.
Secretarybird *Sagittarius serpentarius*	25.46	Mainly eats grasshoppers and small vertebrates. Local population decreases have been reported in South Africa
Martial Eagle *Polemaetus bellicosus*	25.76	Variety of animals, especially birds, mammals and reptiles. Persecuted on farmlands.
African Wood Owl *Strix woodfordii*	28.12	Mainly eats insects and small birds, but also snakes and small mammals.
Southern Yellow-billed Hornbill *Tockus leucomelas*	34.73	Wide range of animals and plant products, doing most of its foraging on the ground, chasing after small animals and picking up fallen fruit.
African Hawk Eagle *Aquila spilogaster*	34.80	Mainly eats birds, typically hunting from a perch from which it intercepts its prey, but also rodents, bats and vervet monkeys
Southern White-faced Scops-Owl *Ptilopsis granti*	35.44	Small mammals, insects and birds. Hunts by flying from perch to perch, trying to locate prey. Once prey is spotted, it descends to the ground to pluck the animal up with its talons.
Wahlberg's Eagle *Aquila wahlbergi*	38.17	Wide variety of animals, especially birds, mammals and reptiles. In some localities its population is decreasing, due to poisoning and habitat transformation.
African Goshawk *Accipiter tachiro*	41.45	Mainly eats birds, supplemented with mammals and lizards. Not threatened, although in Zimbabwe it is threatened by pesticide contamination, while in the Eastern Cape its range has decreased due to habitat loss
White-necked Raven *Corvus albicollis*	55.93	Highly adaptable feeder, eating a variety of insects, birds, small mammals, reptiles and fruit

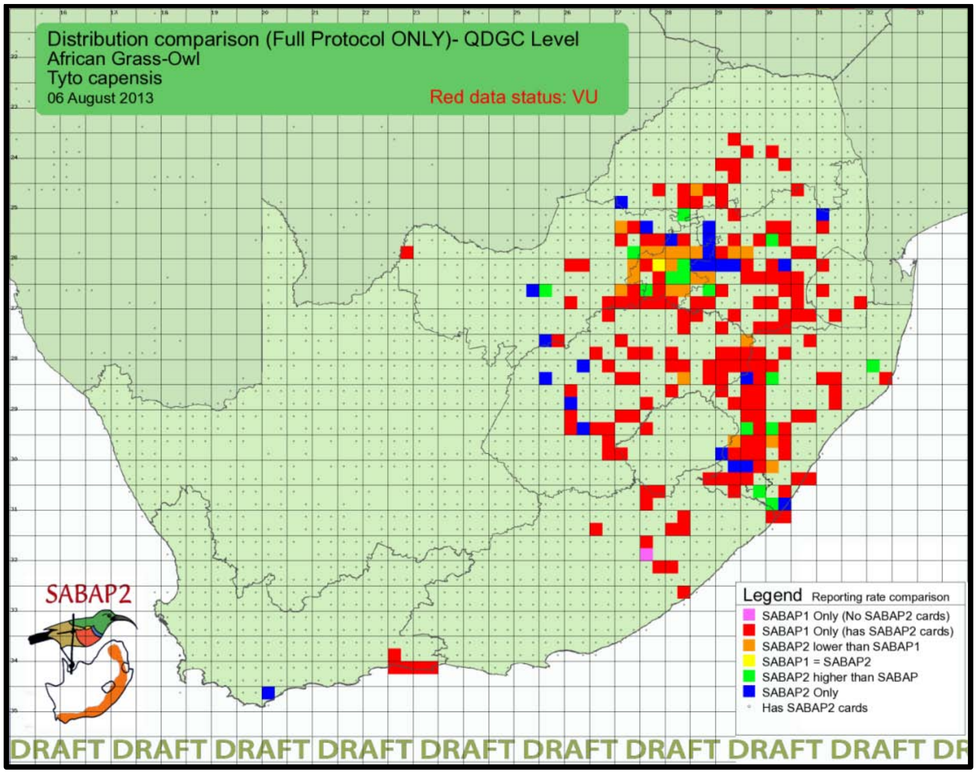

Figure 3.1 Comparison of African Grass-Owl distribution between SABAP1 and SABAP2

References

Allan, D.G. 1988. The Blue Swallow: in with a chance. Quagga 22: 5 –7.

Allan, D.G. 1994. The abundance and movements of Ludwig's Bustard. Ostrich 65: 95–105.

Allan, D.G. 1997. Bittern *Botaurus stellaris*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), p. 79. BirdLife South Africa, Johannesburg.

Allan, D.G. and Earlé, R.A. 1997. Blue Swallow *Hirundo atrocaerulea*. In: The Atlas of Southern African Birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 52−53. BirdLife South Africa, Johannesburg.

Anderson, M.D. 1997. Hadeda Ibis *Bostrychia hagedash*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 108−109. BirdLife South Africa, Johannesburg.

Andrewartha, H.G. and Birch, L.C. 1974. The Distribution and Abundance of Animals. University of Chicago Press, Chicago.

Armstrong, A.J. 1991. On the biology of the Marsh Owl and some comparisons with the Grass Owl. Honeyguide 37: 148–159.

Barnes, K.N. (ed.) 2000. The Eskom Red Data Book of Birds of South African, Lesotho and Swaziland. BirdLife South Africa, Johannesburg.

Barrett, G.W., Silcocks, A.F., Barry, S., Cunningham, R.B. and Poulter, R. 2003. The New Atlas of Australian Birds. Birds Australia, Melbourne.

Benson, C.W. and Irwin, M.P.S. 1966. The Brachystegia avifauna. Ostrich Supplement 6: 297–321.

Berruti, A. 1997. Ayres' Cisticola *Cisticola ayresii*. In: The Atlas of Southern African Birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 294–295. BirdLife South Africa, Johannesburg.

Bezuidenhout, J. D. and Stutterheim, C.J. 1980. A critical evaluation of the role played by the Red-billed Oxpecker *Buphagus erythrorhynchus* in the biological control of ticks. Onderstepoort Journal of Veterinary Research 47(2):51-75.

Bibby, C. 2002. Why conserve bird biodiversity? In: Conserving Bird Biodiversity: General Principles and their Application. Conservation Biology Series 7. Norris, K. and Pain, D.J. (eds), pp 20–33. Cambridge University Press.

BirdLife International. 2013a. Species factsheet: *Bucorvus leadbeateri*. Downloaded from http://www.birdlife.org on 29/07/2013.

BirdLife International. 2013b. Species factsheet: *Hirundo spilodera*. Downloaded from http://www.birdlife.org on 10/07/2013.

BirdLife International. 2013c. Species factsheet: *Sagittarius serpentarius*. Downloaded from http://www.birdlife.org on 30/07/2013.

BirdLife South Africa. 2013a.Official checklist of birds. Downloaded from http://www.birdlife.org.za/checklists on 10/07/2013.

BirdLife South Africa. 2013b. Welcome to BirdLife South Africa. Downloaded from http://www.birdlife.org.za/ on 17/01/2014.

Bird Studies Canada. 2013. Christmas Bird Count. Downloaded from http://www.bsc-eoc.org/volunteer/cbc/ on 17/01/2014.

Boshoff, A.F., Vernon, C.J. and Brooke, R.K. 1983. Historical atlas of the diurnal raptors of the Cape Province (Aves: Falconiformes). Annals of the Cape Provincial Museums (Natural History) 14: 173–297.

Boshoff, A.F. 1997. Martial Eagle *Polemaetus bellicosus*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 192–193. BirdLife South Africa, Johannesburg.

Brown, J.H. 1984. On the relationship between abundance and distribution of a species. American Naturalist 124: 255–279.

Bruderer, B. and Bruderer, H. 1993. Distribution and habitat preference of Redbacked Shrikes *Lanius collurio* in southern Africa. Ostrich 64: 141–147.

Carter, J. 2012. Somerset West – SABAP1 and SABAP2 compared. Ornithological Observations 3: 253−267.

Chapin, J.P. 1923. Ecological aspects of bird distribution in tropical Africa. American Naturalist 57: 106–125.

Cody, M.L. 1985. An introduction to habitat selection in birds. In: Habitat Selection in Birds. Cody, M.L. (ed.), pp. 3–56. Academic Press, London.

Craig, A., Every, B. and Summers-Smith, D. 1987. The spread of the Southern Greyheaded Sparrow in the Cape Province. Annals of the Cape Provincial Museums (Natural History) 16: 191–200.

Craig, A.J.F.K. 1997a. Red Bishop *Euplectes orix*. In: The Atlas of Southern African Birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 578–579. BirdLife South Africa, Johannesburg.

Craig, A.J.F.K. 1997b. Southern Greyheaded Sparrow *Passer diffusus*. In: The Atlas of Southern African Birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 542–543. BirdLife South Africa, Johannesburg.

Crick, H.Q.P. 2004. The impact of climate change on birds. Ibis 146 Supplement 1: 48–56.

Dean, W.R.J. 1973. Analysis of a collection of Barn Owl *Tyto alba* pellets from Warmbaths, Transvaal. Zoologica Africana 8: 75–81.

Dean, W.R.J. and Hockey, P.A.R. 1989. An ecological perspective of lark (Alaudidae) distribution and diversity in the southwest-arid zone of Africa. Ostrich 60: 27–34.

Dean, W.R.J. 1990. African Grass Owl. In: The Complete Book of Southern African Birds. Ginn, P.J., McIlleron, W.G. and Milstein, P. le S. (eds), pp 332. Struik Winchester, Cape Town.

Dean, W.R J. 2005. Eurasian Bittern. In: Roberts' Birds of Southern Africa. 7th Edition. Hockey, P.A.R, Dean, W.R.J. and Ryan, P.G. (eds), pp. 602–603. The Trustees of the John Voelcker Bird Book Fund, Cape Town, South Africa.

del Hoyo, J., Elliot, A. and Sargatal, J. 1992. Handbook of the Birds of the World, Vol. 1: Ostrich to Ducks. Lynx Edicions, Barcelona, Spain.

del Hoyo, J., Elliott, A. and Sargatal, J. 2001. Handbook of the Birds of the World, Vol. 6: Mousebirds to Hornbills. Lynx Edicions, Barcelona, Spain.

De Swardt, D.H. 2012. 2925BD Hagesdam – SABAP1 and SABAP2 compared. Ornithological Observations 3: 109‒122.

Duplantier, J.M., Granjon, L. and Bouganaly, H. 1996. Reproductive characteristics of three sympatric species of *Mastomys* in Senegal, as observed in the field and in captivity. Mammalia 60: 629‒638.

Du Plessis, M.A. 1989. The influence of roost-cavity availability on flock size in the Red-billed Woodhoopoe *Phoeniculus purpureus*. Ostrich Supplement 14: 97–104.

Earlé, R.A. 1997. South African Cliff Swallow *Hirundo spilodera*. In: The Atlas of Southern African Birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 62–63. BirdLife South Africa, Johannesburg.

Eckhardt, H.C., van Wilgen, B.W. and Biggs, H.C. 2000. Trends in woody vegetation cover in the Kruger National Park, South Africa, between 1940 and 1998. African Journal of Ecology 38: 108–115.

Furness, R.W. and Greenwood, J.J.D. (eds). 1993. Birds as Monitors of Environmental Change. Chapman and Hall, London.

Gaston, K.J. 2009. Geographic range limits: achieving synthesis. Proceedings of the Royal Society B − Biological Sciences 276: 1395−1406.

Gentilli, J. 1992. Numerical clines and escarpments in the geographical occurrence of avian species; and a search for relevant environmental factors. Emu 92: 129–140.

Greenwood, J.J.D. 2007. Citizens, science and bird conservation. Journal of Ornithology 148: S77–S124.

Gibbons, D.W., Reid, J.B. and Chapman, R.A. 1993. The New Atlas of Breeding Birds in Britain and Ireland: 1988–1991. T. and A.D. Poyser, London.

Gibbons, D.W., Donald, P.F., Bauer, H., Fornasari, L. and Dawson, I.K. 2007. Mapping avian distributions: the evolution of bird atlases. Bird Study 54: 324−334.

Hancock, J.A., Kushlan, J.A. and Kahl, M.P. 1992. Storks, Ibises and Spoonbills of the World. Academic Press, London.

Harebottle, D.M. and Harrison, J.A. 2001. Changes in distribution and abundance of waterbirds in South Africa. Bird Numbers 10: 1–7.

Harebottle, D.M., Underhill L.G. and Brooks M. 2007. Southern African Bird Atlas Project 2 – Instruction Manual. Animal Demography Unit, University of Cape Town, Cape Town.

Harrison, J.A. 1988. Southern African Bird Atlas Project/Suider-Afrikaanse Voëlatlasprojek. Instructions/Instruksies. Southern African Bird Atlas Project, University of Cape Town, Cape Town.

Harrison, J.A. 1992. The Southern African Bird Atlas Project databank: five years of growth. South African Journal of Science 88: 410–413.

Harrison, J.A. 2000. Changing suburban birds—terrestrial species. Bird Numbers 9: 1–7.

Harrison, J.A. and Navarro, R.A. 1994. Modelled reporting rates as indices of changes in relative abundance with altitude and season. In: Bird Numbers 1992: Proceedings of the 12th International Conference of IBCC and EOAC. Hagemeijer, E.J.M. and Verstrael, T.J. (eds), pp. 607–618. Statistics Nederlands, Voorburg, Heerlen, the Netherlands.

Harrison, J.A. and Underhill, L.G. 1997. Introduction and methods. In: The Atlas of Southern African Birds. Vol. 1: Non-passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. xliii–lxiv. BirdLife South Africa, Johannesburg.

Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds). 1997. The Atlas of Southern African Birds. Vol. 1: Non-passerines. BirdLife South Africa, Johannesburg.

Harrison, J. A., Underhill, L. G. and Barnard, P. 2008. The seminal legacy of the Southern African Bird Atlas Project. South African Journal of Science 102: 82–84.

Hockey, P.A.R., Allan, D.G., Rebelo, A.G. and Dean, W.R.J. 1988. The distribution, habitat requirements and conservation status of Rudd's Lark *Heteromirafra ruddi* in South Africa. Biological Conservation 45: 255–266.

Hockey, P.A.R. 2003. Land invasions: are indigenous expansionists cause for concern? Africa Birds and Birding 8: 35–41.

Hockey, P.A.R., Dean, W.R.J. and Ryan, P.G. (eds). 2005. Roberts' Birds of Southern Africa. 7th edition. The Trustees of John Voeckler Bird Book Fund, Cape Town.

Hockey, P.A.R. and Midgley, G.F. 2009. Avian range changes and climate change: a cautionary tale from the Cape Peninsula. Ostrich 80: 29−34.

Hoffman, T.M. and O'Connor, T.G. 1999. Vegetation change over 40 years in the Weenen/Muden area, KwaZulu-Natal: evidence from photo-panoramas. African Journal of Range and Forage Science 16: 77–94.

Hoffman, T.M. and Rohde, R. F. 2011. Rivers through time: Historical changes in the riparian vegetation of the semi-arid, Winter Rainfall Region of South Africa in response to climate and land use. Journal of the History of Biology 44: 59−80.

Hofmeyr, S.D. 2012. Impacts of environmental change on large terrestrial bird species in South Africa: insights from citizen science data. PhD thesis, University of Cape Town, South Africa. Downloaded from http://www.adu.org.za/pdf/Hofmeyr_S_2012_PhD_thesis.pdf. Accessed 31 July 2013. (31/07/2013).

Huntley, B., Collingham, Y.C., Green, R.E., Hilton, G.M., Rahbek, C. and Willis, S.G. 2006 Potential impacts of climatic change upon geographical distributions of birds. Ibis 148, 8–28.

Kemp, L. 2013. Southern Ground Hornbill – Vanishing Icon. African Birdlife Volume 2, pp 54−57.

Koskimies, P. 1989. Birds as a tool in environmental monitoring. Annales Zoologici Fennici 26: 153–166.

Leirs, H., Verhagen, R. and Verheyen, W. 1993. Productivity of different generations in a population of *Mastomys natalensis* rats in Tanzania. Oikos 68: 53−60.

Low, A.B. and Rebelo, A.G. (eds.) 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Macdonald, I.A.W., Richardson, D.M. and Powrie, F.J. 1986. Range expansion of the Hadeda Ibis *Bostrychia hagedash* in southern Africa. South African Journal of Zoology 21: 331–342.

Maclean, G.L. and Herremans, M. 1997. Burchell's Courser *Cursorius rufus*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 444−445. BirdLife South Africa, Johannesburg.

McIntire, E.J.B., and Fajardo, A. 2009. Beyond description: The active and effective way to infer processes from spatial patterns. Ecology 90: 46–56.

McKenzie, D. 2011. Reporting rate comparisons for birds in the Nelspruit area – SABAP1 vs SABAP2. Ornithological Observations 2: 22−31.

Measey, G.J., Rödder, D., Green, S.L., Kobayashi, R., Lillo, F., Lobos, G., Rebelo, R. and Thirion, J.M. 2012 Ongoing invasions of the African clawed frog, *Xenopus laevis*: a global review. Biological Invasions 14: 2255−2270.

Mendelsohn, J.M. 1989. Habitat preferences, population size, food and breeding of six owl species in the Springbok Flats, South Africa. Ostrich 60: 183–190.

Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J. and Knoepfer, D. 2004. Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland. SI/MAB Series No. 9, Washington, D.C.

Mokotiomela, T.M., Musil, C.F. and Esler, K.J. 2013. Potential seed dispersal distances of native and non-native fleshy fruiting shrubs in the South African Mediterranean climate region. Plant Ecology 214: 1127−1137.

Moreau, R.E. 1966. The bird communities of some African vegetation types. Ostrich Supplement. 6: 265–270.

Mucina, L. and Rutherford, M.C. (eds.). 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitizia 19. South African National Biodiversity Institute, Pretoria, South Africa.

Mundy, P.J. 1997. Yellow-billed Oxpecker *Buphagus africanus*. In: The atlas of southern African birds. Vol. 2: Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 480–481. BirdLife South Africa, Johannesburg.

Nikolaus, G. 2001. Bird exploitation for traditional medicine in Nigeria. Malimbus 23: 45−55.

Norris, C.A. 1960. The breeding distribution of thirty bird species in 1952. Bird Study 7: 129−184.

O'Connor, T.G., Kuyler, P., Kirkman, K.P. and Corcoran, B. 2010. Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland? African Journal of Range and Forage Science 27: 67–76.

O'Connor, T.G. and Chamane, S.C. 2012. Bush clump succession in grassland in the Kei Road region of the Eastern Cape, South Africa, African Journal of Range and Forage Science, 29: 133−146.

Okes N.C., Hockey P.A.R. and Cumming, G.C. 2008. Habitat use and life history as predictors of bird responses to habitat change. Conservation Biology 22: 151−162.

Olsen, P., Weston, M., Cunningham, R. and Silcocks, A. 2003. The state of Australia's birds. Supplement to Wingspan13(4): 1−23.

Osborne, P.E. and Tigar, B.J. 1992. Priorities for bird conservation in Lesotho, southern Africa. Biological Conservation 61: 159–169.

Parker, V. 1996. Modelling the distribution of bird species in Swaziland in relation to environmental variables. Ostrich 67: 105–110.

Parker, V. 1999a. The use of logistic regression in modelling the distribution of bird species in Swaziland. South African Journal of Zoology 34: 39–47.

Parker, V. 1999b. The Atlas of the Birds of Sul do Save, Southern Mozambique. Avian Demography Unit, Cape Town and Endangered Wildlife Trust, Johannesburg.

Parker, V. 2005. The Atlas of the Birds of Central Mozambique. Avian Demography Unit, Cape Town and Endangered Wildlife Trust, Johannesburg.

Parmesan, C., Ryrholm N., Stefanescu C., Hill J.K., Thomas C.D., Descimon H., Huntley B., Lauri K., Kullberg J., Tammaru T., Tennent W.J., Thomas J.A. and Warren M. 1999. Poleward shifts in geographic ranges of butterfly species associated with regional warming. Nature 399: 579–583.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology Evolution and Systematics 37: 637−669.

Parmesan, C. and Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37−42.

Peacock, F. 2012. Chamberlain's LBJs: The Definitive Guide to Southern Africa's Little Brown Jobs. Mirafra Publishing, Pretoria.

Retief, E.F. 2013. 2528AB Pienaarsrivier – analysis of SABAP1 and SABAP2 data for the quarter degree square. Ornithological Observations 4: 107−118.

Robertson, A., Simmons, R.E., Jarvis, A.M. and Brown, C.J. 1995. Can bird atlas data be used to estimate population size? A case study using Namibian endemics. Biological Conservation 71: 87–95.

Robertson, M.P., Villet, M.H., Fairbanks, D.H.K., Henderson, L., Higgins, S.I., Hoffmann, J.H., Le Maitre, D.C., Palmer, A.R., Riggs, I., Shackleton, C.M. and Zimmermann, H.G. 2003. A proposed prioritization system for the management of invasive alien plants in South Africa. South African Journal of Science 99: 37−43.

Root, T.L., Price, J.T., Hall, K.R, Schneider, S.H., Rosenzweig, C. and Pounds, J.A. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57-60.

Rowan, M.K. 1963. Range of the Cliff Swallow. Ostrich 34: 181–182.

Rosenzweig, C., Casassa G., Karoly D.J., Imeson A., Liu C., Menzel A., Rawlins S., Root T.L., Seguin B. and Tryjanowski, P. 2007. Assessment of observed changes and responses in natural and managed systems. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J. van der and Hanson, C.E. (eds), pp 79−131 Cambridge University Press, Cambridge, UK.

Rutherford, M.C. and Westfall, R.H. 1994. Biomes of southern Africa: an objective characterization. Memoirs of the Botanical Survey of South Africa 54: 1−98.

Saether, B.E., Ringsby, T.H. and Roskaft, E. 2007. Life history variation, population processes and priorities in species conservation: towards a reunion of research paradigms. Conservation 77: 217−226.

Sexton, J.P., McIntyre, P.J., Angert, A.L. and Rice, K.J. 2009. Evolution and ecology of species range limits. Annual Review of Ecology, Evolution and Systematics 40: 415−436.

Sharrock, J.T.R. 1976. The Atlas of Breeding Birds in Britain and Ireland. T. and A. D. Poyser, Berkhamsted.

Siegfried, W.R., Frost, P.G.H., Cooper, J. and Kemp, A.C. 1976. South African Red Data Book – Aves. South African National Scientific Programmes Report 7: 1−108.

Simmons, R.E. 1997a. Bateleur *Terathopius ecaudatus*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 202–203. BirdLife South Africa, Johannesburg.

Simmons, R E. 1997b. Tawny Eagle *Aquila rapax*. In: The Atlas of Southern African Birds. Vol. 1: Non-Passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. and Brown, C.J. (eds), pp. 178–179. BirdLife South Africa, Johannesburg.

Simmons, R.E., Barnard P., Dean W.R.J., Midgley G F., Thuiller W. and Hughes G. 2004. Climate change and birds: the perspectives and prospects from southern Africa. Ostrich 754: 295–306.

Simmons, R.E. 2005a. Bateleur *Terathopius ecaudat.* In: Roberts' Birds of southern Africa, 7th edition. Hockey, P.A.R., Dean, W.R.J. and Ryan, P.G. (eds). pp. 498−500. The Trustees of the John Voelcker Bird Book Fund, Cape Town.

Simmons, R.E. 2005b. Tawny Eagle *Aquila rapax.* In: Roberts' Birds of southern Africa, 7th edition. Hockey, P.A.R., Dean, W.R.J. and Ryan, P.G. (eds). p 529−530. The Trustees of the John Voelcker Bird Book Fund, Cape Town.

Simmons, R.E. 2005c. Martial Eagle *Polemaetus bellicosus.* In: Roberts' Birds of southern Africa,7th edition. Hockey, P.A.R., Dean, W.R.J. and Ryan, P.G. (eds). Pp.538−539. The Trustees of the John Voelcker Bird Book Fund, Cape Town

Sinclair, I., Hockey, P. and Tarboton, W. 2002. Birds of Southern Africa. Second Edition. Struik Publishers, Cape Town.

Sirami, C. and Monadjem, A. 2012. Changes in bird communities in Swaziland savannas between 1998 and 2008 owing to shrub encroachment. Diversity and Distributions 18: 390–400.

Stutterheim, C.J. and Brooke, R.K. 1981. Past and present ecological distribution of the Yellow-billed Oxpecker in South Africa. South African Journal of Zoology 16: 44–49.

Tarboton, W.R. 1980. Avian populations in Transvaal savanna. In: Proceeding ofthe Fourth Pan-African Ornithological Congress. Johnson, D.N. (ed.), pp. 113–124. Southern African Ornithological Society, Johannesburg.

Tyson, P.D. 1986. Climatic Change and Variability in Southern Africa. Oxford University Press, Cape Town.

Underhill, L.G. and Gibbons, D. 2002. Mapping and monitoring bird populations: their conservation uses. In: Conserving Bird Biodiversity: General Principles and their Application. Norris, K. and Pain, D.J. (eds), pp 34−60. Cambridge University Press, Cambridge.

Underhill, L.G., Harebottle, D.M. and Brooks, M. 2013. Southern African Bird Atlas Project 2 (SABAP2): Report for Steering Committee Teleconference 6 June 2013.

Underhill, L.G. and Hockey, P.A.R. 1988. The potential of the Southern African Bird Atlas Project for long-term population monitoring. In: Long-term data series relating to southern Africa's renewable natural resources. Macdonald, I.A.W. and Crawford, R.J.M. (eds), pp. 468–475.

Underhill, L.G. 2012. Martial Eagle spirals downwards. Southern African Bird Atlas Project 2 (SABAP2) News Item 2384. Downloaded from http://sabap2.adu.org.za/news.php?id=2384 on 31/07/2013.

Underhill, L.G. 2013. On this Threat Thursday we pay attention to the Black Stork, a species which is not doing well in our region. Southern African Bird Atlas Project 2 (SABAP2) News Item 3935. Downloaded from http://sabap2.adu.org.za/news.php?id=3935 on 31/07/2013.

Vardien, W., Richardson, D.M., Foxcroft, L.C., Thompson, G.D., Wilson, J.R.U. and Le Roux, J.J. 2012. Invasion dynamics of Lantana camara L. (*sensu lato*) in South Africa. South African Journal of Botany 81: 81−94.

Vernon, C.J. 1972. An analysis of owl pellets collected in southern Africa. Ostrich 43: 109–124.

Vivian-Smith, G., Gosper, C.R., Stansbury, C. and White, E. 2006. Weed invasions: taking a bird's eye view of fleshy-fruited alien invaders. Plant Protection Quarterly 21: 139−141.

VSN International. 2012. GenStat for Windows, 15th Edition. VSN International, Hemel Hempstead, UK.

Walter, H. 1979. Vegetation of the Earth and Ecological Systems of the Geobiosphere. Springer, New York.

Ward, V.L., Oschadleus, H.D and Upfold, L. 2004. Southern Greyheaded Sparrows *Passer diffusus* range expansion in the Western Cape. Afring News 33: 18–20.

Watson, R.T. 1988. The biology, ecology and population dynamics of the Bateleur Eagle (*Terathopius ecaudatus*). Unpublished PhD thesis, University of the Witwatersrand, Johannesburg.

Webster, R. and Oliver, M.A. 2007. Geostatistics for Environmental Scientists, 2nd Edition. Wiley, Chichester.

Wiens, J.J. and Graham, C.H. 2005. Niche conservatism: Integrating evolution, ecology, and conservation biology. Ecology, Evolution and Systematics 36: 519–539.

Wigley, B.J., Bond, W.J. and Hoffmann, M.T. 2009. Bush encroachment under three contrasting land-use practices in a mesic South African savanna. African Journal of Ecology 47: 62–70.

Wigley, B.J., Bond, W.J. and Hoffman, M.T. 2010. Thicket expansion in a South African savanna under divergent land use: local versus global drivers? Global Change Biology 16: 964–976.

Wilson, D.E. and Reeder, D.M. 2005. Mammal Species of the World: A Taxonomic and Geographic Reference. Johns Hopkins University Press, Baltimore.

Winterbottom, J.M. 1968. A check list of the land and fresh water birds of the western Cape Province. Annals of the South African Museum 53: 1–276.

Winterbottom, J.M. 1972. The Mopane Avifauna. South African Avifauna Series 88. Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Cape Town.

Winterbottom, J.M. 1978. Birds. In: Biogeography and Ecology of Southern Africa. Vol. 2. Werger, M.J.A. (ed.), pp. 949–979. Junk, The Hague.

Wirminghaus, J.O. 1989. The diet of barn owls at a roost near Grahamstown. South African Journal of Zoology 24: 232–234.