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Estimating conservation metrics from atlas data: the case of southern African endemic birds

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Summary

The robust assessment of conservation status increasingly requires population metrics for species that may be little-researched, with no prospect of immediate improvement, but for which citizen science atlas data may exist. We explore the potential for bird atlas data to generate population metrics of use in red data assessment, using the endemics and near-endemic birds (endemics) of southern Africa. This region, defined here as South Africa, Lesotho and Swaziland, is home to a large number of endemic bird species and an active atlas project. The Southern African Bird Atlas Projects (SABAP) 1 and 2 are large scale citizen science data sets, consisting of 100’000s of bird checklists and >10 million bird occurrence records on a grid across the subcontinent. These data contain detailed information on species' distributions and population change. For conservationists, metrics that guide decisions on the conservation status of a species for red listing can be obtained from SABAP, including range size, range change, population change, and range connectivity (fragmentation). We present a range of conservation metrics for these bird species, focusing on population change metrics together with an associated statistical confidence metric. Population change metrics correlate with change metrics calculated from dynamic occupancy modelling for a set of 191 common species. We identify four species with neither international nor local threatened status, yet for which bird atlas data suggest alarming declines, and two species with threatened status for which our metrics suggest could be reconsidered. A standardized approach to deciding the conservation status of a species is useful so that charismatic or flagship species do not receive disproportionate attention, although ultimately conservation status of any species must always be a consultative process.

Keywords

Conservation status, population change, citizen science

Introduction

In a world with biodiversity under increasing threat from anthropogenic activities, it can be difficult to prioritize the limited resources available to conservationists. Big, charismatic species may receive a disproportionate share of resources at the expense of small, non-descript or inaccessible species (Leader-Williams and Dublin, 2000). Systematic, objective ways of determining conservation status are thus increasingly important in a world in which conservation is easily driven by emotional rather than logically defensible criteria.

The understanding of bird distributions and how they are changing is crucial information for effective bird conservation (Gaston, 2003). In order to determine the conservation status of any species, information is needed on range size, population size and population trend (IUCN Standards and Petitions Subcommittee, 2014). Furthermore, information on habitat integrity and population fluctuations is also considered where available. However, these data are lacking for most species globally.

We explored ways of facilitating the conservation assessment process in regions of the world with atlas data. Here we focus on southern Africa, defined for this purpose as South Africa, Lesotho and Swaziland. In South Africa alone, there are over 600 species of breeding birds in a country of 1.2 million km^2, making biodiversity monitoring a challenging task (Taylor, *et al.*, 2015). However, the region is increasingly known internationally for its high-quality long-term, large-scale public participation projects. Such citizen science projects make it possible for observations made by many different people to be pooled and analysed as a whole (Cohn, 2008). The first and second Southern African Bird Atlas Projects (SABAP1, 1987–1992, and SABAP2, 2007–present) are among Africa's biggest biodiversity databases, and provide overviews of avian distribution across southern Africa approximately 20 years apart (Harrison, *et al.*, 2008). Spatial records in this database show changes in species' distributions (range), and by comparing reporting rates (the proportion of checklists reporting a species - a proxy for relative abundance) between these projects we can estimate population change. This information has been used to examine issues of conservation interest, including the influence on birds of climate change (Walther and Niekerk, 2014); identification of non-climatic drivers of range change (Péron and Altwegg, 2015a) and changes in timing of migration (Bussière*, et al.*, 2015), as well as other questions of ecological interest (e.g. Péron and Altwegg, 2015b, Péron and Altwegg, 2015c). A few publications (e.g. Kemp*, et al.*, 2001, Lee and Barnard, 2015) have used this information to inform conservation decisions for some species, but despite evidence that reporting-rate declines are related to observed population decline (Amar*, et al.*, 2015), there has been little testing of the robustness of these measures and they have not been used formally at a national scale to inform conservation decisions.

We explore the capacity of this atlas project to support conservation status assessment by overviewing the information that can be obtained from the SABAP projects for 58 southern African endemic and near-endemic bird species. We present population change indices together with a measure of statistical confidence in these, as well as range-size, range-size change and range connectivity metrics. This information should be important for those evaluating the conservation status of these species in southern Africa.

Methods

SABAP data

The SABAP data sets consist of bird lists compiled by birding citizen scientists. SABAP1 used quarter degree grid cells (grid cells, 15’x15’) as the sampling unit, corresponding to standard southern African 1:50,000 topographical maps (Harebottle*, et al.*, 2007). The SABAP2 spatial sampling unit is the 5’x5’ pentad. There are nine pentads nested within each grid cell, so we aggregated the data of the second phase, SABAP2, at the quarter degree resolution in order to compare both phases. Birders were asked to submit lists of all species that they saw or heard during visits to grid cells of between two hours and five days. As of 2014 SABAP2 data existed for over 3,000 grid cells, with country-wide coverage illustrated used in our analysis displayed in Figure 1.

We consider those species with >70% of range or population within South Africa, Lesotho and Swaziland as near-endemics, as listed by Birdlife South Africa (BLSA, Lotz*, et al.*, 2014). We used this list to obtain the national and global conservation status (Least Concern, LC, to Endangered, EN) for these species. We restrict our analysis to this subset of the >840 species in the SABAP database, as population trends identified for endemics and near-endemics can be more accurately inferred from this analysis than for species with significant ranges outside the survey area.

Of the 69 endemics on the above list, we consider 58 after excluding those with recent taxonomic splits. Several species in the BLSA checklist have been split since SABAP1 and are represented as two or more species in SABAP2. We do not consider new southern African species split from species with a combined range that extends beyond the study area. This includes: Hottentot Buttonquail *Turnix hottentottus*, Karoo Thrush *Turdus smithi*, Cape Parrot *Poicephalus robustus*, and the Long-billed Lark complex. The data used in this analysis were accessed from the SABAP2 database over 29 – 30 May 2014.

Reporting rate

The reporting rate is the number of times a species was reported in a grid cell divided by the total number of checklists for that grid cell. There is evidence that reporting rates are monotonically related to abundance (Amar*, et al.*, 2015, Griffioen, 2001, Robertson*, et al.*, 1995). Reporting rate data are publicly available for each species from http://sabap2.adu.org.za/ and are a useful first step in quantifying changes in abundance (e.g. Huntley*, et al.*, 2012). For between-atlas period comparisons we select only the subset of data that were sampled on at least two occasions during each atlas period (n = 2,005 grid cells). We calculate a summary *reporting rate change* metric based on the average reporting rate across all grid cells for each project for which a species was ever present:

(mean SABAP2 reporting rate – mean SABAP1 reporting rate)/mean SABAP1 reporting rate where positive values indicate increase, and negative values indicate decrease. We express this ratio as a percentage. The premise behind this metric is based on the concept of the regression to the mean: while extreme results on a site by site basis certainly exist, the mean across the population should tend towards a stable range of values.

As reporting rate change within a grid cell is undefined if the species was not recorded in that cell during SABAP1, due to division by zero, we create a standardized index of *population change* that allows us to present variation in change across a species range. For each grid cell we calculated the population change metric as follows:

SABAP2 reporting rate / (SABAP1 reporting rate + SABAP2 reporting rate) - 0.5

This metric returns a value between -0.5 and 0.5, with values > 0 indicating increases, and values < 0 indicating declines (adapted from Amar, *et al.*, 2010). A population change map for each species is available as electronic supplementary information, together with reporting rate and range change maps. For an overview of population trends across southern Africa for this set of species, we calculate the mean of population change across all species from within each grid cell as a population change map. We correlate the population change metric against each of the further metrics described below using Pearson's product-moment correlations in R (R Core Team, 2015).

As a final visual representation of change, based on list data for the set of endemic birds, we calculate the ratio of lists with a species recorded to lists without that species for each atlas period. This is the presence/absence ratio (presented in Cunningham, *et al.*, 2016). The log of the mean of these metrics across all grid cells plotted against each other allows a visualization of species that are doing well in SABAP2 compared to SABAP1 as a function of range. We emphasize that species close together on the resulting chart do not necessarily have similar populations, as the reporting rates are influenced by species detectability; for instance large or vocal species are likely reported more frequently than expected given density.

The standard statistic for the equality of two proportions (z-score; Underhill and Bradfield, 1998) can be used as an index to measure confidence in change in relative abundance that accounts for the number of lists submitted for each grid cell for each period. The following is the formula as described in Underhill and Brooks (2014):

$$Z = \frac{P2 - P1}{\sqrt{\left(P(1-P)\left(\frac{1}{n1} - \frac{1}{n2}\right)\right)}}$$

where P1 and P2 are the reporting rates from SABAP1 and SABAP2 respectively, n1 and n2 are the numbers of checklists on which the reporting rates are based, and P, reporting rate, is given by:

$$P = \frac{n1P1 + n2P2}{n1 + n2}$$

We calculate the mean of the z-score for the grid cells in a species range as an index of confidence in the direction of population change for each species: large negative values indicate evidence for population decline, large positive values indicate evidence for population increase. Values close to zero indicating unclear status: populations could be declining, increasing or not changing.

Population change metric validation with dynamic occupancy modelling

Treating reporting rate as a proxy for abundance relies on the premise that variation in detection probability is largely due to variation in abundance. This assumption is shared with other abundance estimators that are based on detection / non-detection data (Péron and Altwegg, 2015a, Royle and Nichols, 2003) and appears to be reasonable for the SABAP data (Huntley, *et al.*, 2012, Robertson, *et al.*, 1995). We also assume that the trends in species abundance in areas not well covered (notably the arid central western regions) were similar to those in well-covered areas. As we cannot validate these assumptions and it has been shown that simple metrics can produce biased trend estimates when sampling is not considered (Isaac, *et al.*, 2014), we test the population change metric described above against 'probability of reporting' change between atlas periods based on 191 common species from dynamic occupancy modelling methods proposed by Bled, *et al.* (2013) and presented in Péron and Altwegg (2015a). These models attempt to account for variation in detectability that is a consequence of observer, habitat and season. However, due to the large number of variables these models are unstable for species with low reporting rates and small ranges i.e. most of the species in our set of endemic birds.

We present correlation coefficients at the community level using mean values for each species based on the summary metrics explained above and probability of reporting change for the set of 191 bird species. We also examine correlation between population change scores and z-scores with probability of reporting change for each of the 20 endemic species at the QDGC level within the set of 191 birds. Lastly, we examine the relationship between the correlation coefficient output for the last analysis with the 20 endemic species with the log-normalised number of QDGCs to examine the influence of range size on these comparisons.

Range and range change

Between atlas periods, ranges of some species expanded while others have contracted. To capture a snapshot of net gain or loss in range, we use the following calculation based on grid cells in which a species has been recorded:

(count of grid cells from SABAP2 – count of grid cells from SABAP1) /count of grid cells from SABAP1

Plotting reporting rate change against range change is useful for gauging how well a species is doing compared to other species.

To exclude that range where perhaps a species was vagrant or possibly incorrectly recorded in SABAP1, we excluded grid cells that had >50 lists but only 1 record in SABAP1 and call this core range. We calculated core range change as above for range change; but this is a stricter measure of range change.

We calculated the total number of grid cells from where a species was recorded over both atlas periods. This value multiplied by the approximate area covered by a grid cell, 729 km^2, we call the species SABAP range, which we consider a surrogate for Extent of Occurrence (EOO; the minimum convex polygon encompassing all known normal occurrences of a particular species). We compare these to ranges from Birdlife International species accounts from BirdLife Data Zone (http://www.birdlife.org/datazone/home) using standard correlation tests in R (R Core Team, 2015). We also calculate the area of pentads from which a species has been recorded and treat this finer scale reporting as an indication of Area of Occupancy (AOO; the subset of the EOO where the species actually occurs).

Connectivity index

For each species we calculated a range connectivity score. Each grid cell where a species was recorded was scored for the presence of the species in the four neighbouring grid cells to the north, south, west and east, being those grid cells with greatest surface area contact. The maximum score is four for a grid cell surrounded by other occupied grid cells, while an isolated grid cell will have a score of 0. For each species we record the mean connectivity score across the species range. This index may be influenced by detection probability: a species with a checker-board pattern might occur widely but be hard to detect (e.g. Peregrine Falcon *Falco peregrinus*). As this score is a function of the area of a species range, we correct by dividing the connectivity score by the log of the number of grid cells in which a species occurs.

Results

Population change for southern African endemics in relation to reporting rate and range change

Displaying population metrics for this set of species allows one to examine individual species trends in the broader context of species trends for the region. In the example of what we call southern African endemics, population trends were mixed, with mean reporting rate lower for 33 species, and higher for the remaining 25 (mean population change = -0.06 ± 0.09). There was a correlation between range change and reporting rate change ($t = 6.7$, $p < 0.01$, $df = 56$, Figure 2); as, generally, if a species is no longer reported from a grid cell this is reflected in both metrics. A species with reporting rate change < -30% and range change < -30% (bottom left Figure 2, Figure 3) may be a species of conservation concern based on IUCN criteria A (population size reduction), where population reduction (measured over the longer of 10 years or 3 generations) is greater than 30%. Several species with positive range and reporting rate change metrics are still species of conservation concern, as there may be reasons other than population change metrics for considering their status (e.g. population size and fragmentation).

There are four species currently listed as species of Least Concern that merit further investigation into their conservation status: Ground Woodpecker, Drakensberg Rockjumper, Sentinel Rock Thrush and Gurney's Sugarbird (Figure 3). All these species are associated with upland areas or the grassland biome, as are the three species with existing threatened status in Figure 3. Confidence in population change (mean z-score) of species of conservation concern was lowest for Botha's Lark, but the total number of grid cells where the species was ever recorded was only 20. The associated range change for Botha's Lark between atlas periods was -64%. The total core range of this species was 15 grid cells, with a range change of -50%: an alarming apparent contraction.

The seven species identified in Figure 3 as species of conservation concern are all species for which the confidence measure (mean z-score) across grid cells was within the lower quartile of values for the total set of species (Table 1). In addition to the above species, those species with large measures of confidence in decrease (negative z-scores) were: Orange-breasted Sunbird, Cape Rockjumper, Protea Seedeater, Pied Starling and Grey-winged Francolin. For these species we are more confident there are population declines possibly as they are associated with areas with large atlasing efforts, although the magnitude of these declines may not necessarily meet IUCN criteria for threatened status without concurrent declines in reporting rate. Presence/absence ratios for Protea Seedeater, Grey-winged Francolin and Pied Starling are low (Figure 4) and appear among the set of species faring most poorly according to this measure.

The set of species for which we are most confident of population declines are those associated with grassland and fynbos (a biome restricted mostly to the Western and Eastern Cape provinces (Cowling, 1995); Table 1, Figure 5). The overview map of population change suggests endemic species as a whole are faring particularly poorly around Swaziland and north-eastern South Africa. The fynbos biome (a fire driven ecosystem dominated by shrubs, geophytes and the Restionaceae family (Cowling, 1995)) in South Africa's most south western corner is also an area with largely negative trends.

Population change metric validation with dynamic occupancy modelling

For a set of 191 passerine species for which probability of reporting change was calculated from dynamic occupancy modelling (Peron and Altwegg 2015a), at the community level there was a significant positive correlation with both our population change metric ($r_s = 0.46$, $t = 7.1$, $df = 189$, $p < 0.001$) and mean z-scores ($r_s = 0.56$, $t = 9.3$, $df = 189$, $p < 0.001$). However, in the analysis at the species level for the 20 endemic species for which we had occupancy estimates at the grid level, 13 species showed a significant positive correlation between the dynamic occupancy modelling probability of reporting change and population change; while 15 species showed significant correlation with z-scores. Lastly, the size of range seemed to influence this relationship as there was a significant negative correlation between correlation coefficient output from the above analyses and range size for the 20 endemics ($r_s = -0.79$, $t = -5.3$, $df = 18$, $p < 0.001$) suggesting this relationship between occupancy model metrics and our metrics is weak for species with smaller ranges.

Range

The SABAP ranges of endemic and near-endemic species in southern Africa were generally large (>20,000 km^2; an IUCN threshold criteria for determining threatened species status). SABAP range and published EOO values were highly correlated, with those from SABAP lower on average (BLI EOO 348,306 km^2; SABAP range 291,939 km^2; $t = 16.7$, $p < 0.01$, df = 56). Only two species had total ranges <20,000 km^2: Botha's Lark and Rudd's Lark. Overall, occupied area as calculated from pentad data was on average 23.6% of that of SABAP range. Apart from Rudd's and Botha's Larks, only Mountain Pipit had the pentad area close to 2,000 km^2, representing that AOO threshold under which a species might meet conservation status criteria. There was no correlation between population change and SABAP range ($t = 0.1$, $p = 0.91$, df= 56); or the pentad area from which a species was recorded ($t = 1.4$, $p = 0.16$, df = 56).

Range connectivity

Metrics of connectivity varied widely among the set of endemic bird species. Species identified as those of conservation concern by Lotz*, et al.* (2014) dominated the cluster of species with high fragmentation and small ranges, both corrected and un-corrected (Table 1, Figure 6). There was a significant positive correlation between the corrected connectivity score and population change ($t = 2.6$, $p = 0.01$, df = 56) with species with negative population change also those species with low connectivity. Pied Starling, a widely distributed arid-zone generalist, had the highest connectivity overall. On the other hand, the arid-zone Cinnamon-breasted Warbler had the lowest connectivity score.

Discussion

Citizen science projects like bird atlas projects have an important role to play in biodiversity conservation (Robertson*, et al.*, 2010). In this article we have shown ways in which species atlas data can be used to develop population parameters that can assist conservation assessment of bird species. However, we regard our analysis as only one approach to be used alongside other lines of evidence when assessing the conservation status of species. In our case study from southern Africa, SABAP2 is a dynamic dataset which facilitates the exploration of numerous ecological and conservation questions. It has been effective as 'an early warning system' to alert conservationists of species in trouble (Barnard and Villiers, 2012, Lee and Barnard, 2012).

Population change

Both Loftie-Eaton (2014) and Péron and Altwegg (2015a) found evidence that the species sets that they examined using atlas data were reported more frequently during SABAP2. The latter study of 191 widely distributed species reported only increases in probability of recording between atlas periods. In contrast to these two studies, several endemic species from our study show evidence for population declines.

In southern Africa, the five worst-faring birds by standardized population change have high affinities to the grassland biome or mountain regions. Of these, Botha's Lark has been identified as Endangered. However, we identify four species listed as Least Concern that show changes in population status and range size which qualify them as species of conservation concern: Ground Woodpecker, Sentinel Rock Thrush, Drakensberg Rockjumper and Gurney's Sugarbird. It has been noted that Gurney's Sugarbird is adversely impacted by inappropriate fire regimes (de Swardt, 2010), but there is little published on the other species. It has previously been shown using SABAP data that the species diversity of grassland birds generally, and globally threatened grassland birds in particular, is significantly and negatively correlated with the extent of afforestation (Allan*, et al.*, 1997). Furthermore, climate envelope modelling suggests that fynbos and grassland bird species are among those most at risk from global climate change (Huntley and Barnard, 2012). Our analysis suggests that some species of this biome are in detectable decline over the relatively short period of time between atlas periods.

Several species with grassland affinities show signs of positive population change: Cloud Cisticola, Melodious Lark, Mountain Pipit and Southern Bald Ibis. However, long term monitoring suggests that Southern Bald Ibis continues to show moderate declines at breeding sites, with a breeding population of < 2000 pairs (C. Henderson, unpublished). This species is a colonial breeder that often forages in groups. Bird atlas data may not be a sufficiently sensitive early warning tool for population declines of charismatic or predictably flocking species, as their abundance is not directly recorded and so even large declines in mean flock size would not be reflected in some cases. However, this does suggest that Pied Starling and Grey-winged Francolin, species fitting this description where declines have been observed, may be worthy of special attention. Mountain Pipit shows an unusual situation that reporting rate change was very positive between SABAP1 and SABAP2, which may be a consequence of small range size, for which these summary metrics become unstable. The range for Mountain Pipit showed moderate decrease, and total current range may be under 20,000 km^2 within South Africa. Melodious Lark, currently with IUCN red list status Near Threatened attributed to moderately rapid population decline, is likely stable. Our analysis supports the most recent local regional ranking of Least Concern (Taylor*, et al.*, 2015).

Species with high affinity for forest generally showed little sign of population decreases. Knysna Warbler appears to have expanded its range eastwards despite lower coverage in this part of the species range during SABAP2. This species still exhibits a low degree of range connectivity due to its reliance on isolated forest patches. Knysna Woodpecker was the species that fared the best of all the endemics by various criteria. It is classified as Near Threatened due to historical loss of range from the east coast, coupled with small estimated populations within protected areas. However, population is currently stable, and in the absence of further threats this species might be classified as Least Concern.

Two arid zone species showed core range change declines of >35%: Sclater's Lark and Black-eared Sparrow-lark. Cinnamon-breasted Warbler showed reporting rate declines of >30% and very low range connectivity. There are concerns for bird populations of southern Africa's arid zones, as this area is experiencing dramatic increases in extreme heat events (Cunningham*, et al.*, 2013). However, the area has been poorly covered during SABAP2 and by contrast Red Lark showed increases in reporting rate and moderate range increases. There is thus a continued need for improved atlas coverage of dry regions before concrete conclusions can be made regarding arid-zone species using atlas data.

Birds with affinity for fynbos generally also fared poorly, with Protea Seedeater and Cape Rockjumper showing declining trends. Cape Rockjumper has been identified as vulnerable to warming due to climate change (Lee and Barnard, 2015), while Protea Seedeater declines can be attributed to decrease in mature *Protea* sp. and associated food stands as well as nesting sites (Lee and Barnard, 2014). Several species with fynbos and grassland affinity appear to be faring poorly, including Black Harrier, Ground Woodpecker and Grey-winged Francolin. By contrast, Cape Bulbul, Victorin's Warbler and Cape Grassbird show positive population change trends.

Range

The area encompassed by grid cells best fits the IUCN definition of Extent of Occurrence (EOO), defined as that area that can measured by a minimum convex polygon and which contains all sites of occurrence. However, for species with fragmented range due to poor coverage, this area would currently under-represent the technical definition of EOO. Species with EOO <20,000km^2 may qualify for endangered status if this range is also severely fragmented combined with continuing observed decline in population metrics or extreme population fluctuations. The two species meeting these criteria are Rudd's and Botha's Larks, both currently classified as Endangered.

Range connectivity

Species with small, highly fragmented ranges are traditionally those species most at risk from a conservation perspective (Bolger*, et al.*, 1991). Sclater's Lark, Cinnamon-breasted Warbler and Black-eared Sparrow-lark are three arid-zone species with low scores. The scores of arid zone specialists may be influenced by poor coverage in the arid western and interior of South Africa. On the other hand, forest species like Chorister Robin-chat, Forest Buzzard and Knysna Warbler would be expected to have a fragmented distribution as afromontane forest is a naturally fragmented biome in South Africa. The low connectivity for the upland or grassland species Yellow-breasted Pipit and Sentinel Rock-Thrush is unexpected give the extent of their respective preferred biomes.

Conclusions

We have shown how species atlas datasets, using the example of the Southern African Bird Atlas Project, can be used to extract simple population metrics for use in developing conservation status assessments, even where detailed research on species is unavailable. Our set of southern African endemic and near-endemic bird species shows evidence for population declines among several species. This fits the global pattern that range-restricted species are more vulnerable to patterns of global change. Across southern Africa there is concern that range-restricted species will increasingly have no climate envelope space in which to move (Huntley*, et al.*, 2012).

While we concentrate on southern African endemic bird species, this region hosts considerable populations of bird species with global conservation status that we have not considered in this assessment, such as Blue Swallow *Hirundo atrocaerulea*, Bearded Vulture *Gypaetus barbatus* and several crane species. While some of the techniques introduced here, such as standardized population change in conjunction with z-scores can be used for these species, there are further caveats to the interpretation of these species, as accounting for movements and range changes elsewhere are difficult to account for.

In order to interpret atlas data, greater use should be made of statistics that standardize reporting rates over as wide an area as possible, and greater use should be made of occupancy modelling that accounts for various issues related to detection arising from observer and seasonal affects (e.g. Bled*, et al.*, 2013), for species with sufficiently large ranges. The metrics we used in this study rely on the assumption that the probability of detecting a species at a site is dominated by its local abundance and otherwise reasonably constant (Guillera-Arroita*, et al.*, 2015). In contrast, occupancy- and related models allow for modelling the observation process in more detail (Altwegg*, et al.*, 2008, MacKenzie*, et al.*, 2006, Royle and Nichols, 2003). However, for species with small ranges compared to the spatial sampling unit, statistically separating the observation process from the biological process can be challenging. In these cases, we argue that comparisons based on raw data can still be useful, provided that they are interpreted with appropriate care. In spite of the difficulties in interpretation of changes in reporting rates between SABAP1 and SABAP2, it is likely that if the SABAP2 results for a species shows decreased reporting rates (or complete absence) over large parts of its range, this reflects genuine range change, as comparisons are more likely to be conservative than to exaggerate increases or decreases (Loftie-Eaton, 2014). With SABAP2 entering its 7th year with consistent reporting for the last five years, this project will in the near future provide information on population change in its own right. There is thus every reason to continue to encourage the citizen scientists who collect these data to continue doing so, and thus add value to one of Africa's largest, and certainly most accessible and vibrant biodiversity databases.

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Table 1: Population trend summary metrics for the southern African endemic bird species, arranged by population change. Names are according to Hockey, *et al.* (2005) with South Africa endemics indicated by *. Habitat indicates preferred biome/s. SA status: Conservation status according to Taylor, *et al.* (2015). Global Status: IUCN conservation status. RR change: reporting rate change; Pop change: mean of the standardized population change and standard deviation (sd); range change: difference of grid cells between SABAP2 and SABAP1, divided by grid cell count from SABAP1; Core range change: as for previous but excluding grid cells with low reporting rate; mean z: the mean of the z-scores across grid cells; mass in grams; SABAP2 range: grid cell count * 729, approximate range in km^2; All SABAP range: grid cell count for any grid cell from which a species was recorded in either atlas *729; Pentad area: count of pentads from which a species was recorded in SABAP2 * 81; Fragment score: index from 0 (isolated) to 4 (completely connected). Values in bold: RR change < -30%; Pop change < -0.25; Range and core range change < -30%; mean-z < -0.9; SABAP2 and All SABAP range < 20,000; Pentad area < 2,000; Fragment score < 1.5.

Name	Latin name	Habitat	SA status	Global Status	RR change	Pop change	sd	Range change	Core range change	mean z	mass	SABAP2 range	All SABAP range	Pentad area	Fragment score
Botha's Lark *	*Spizocorys fringillaris*	Grass	EN	EN	**-45.95**	**-0.272**	0.39	**-64.71**	**-50.00**	-0.175	19	**4374**	**14580**	**1053**	**1.2**
Ground Woodpecker	*Geocolaptes olivaceus*	Grass, Fynbos	LC	LC	**-51.67**	-0.246	0.33	**-43.25**	**-39.53**	**-1.108**	120	199017	398763	44145	2.64
Sentinel Rock Thrush	*Monticola explorator*	Grass, Fynbos	LC	LC	**-34.44**	-0.229	0.36	**-48.74**	**-38.46**	-0.625	47	105705	235467	20088	2.21
Drakensberg Rockjumper	*Chaetops aurantius*	Grass	LC	LC	-28.53	-0.207	0.34	**-42.03**	**-35.48**	-0.669	50	32076	63423	5184	2.45
Gurney's Sugarbird	*Promerops gurneyi*	Grass	LC	LC	**-43.51**	-0.204	0.34	**-40.38**	**-35.16**	-0.574	35	45198	87480	9882	1.88
Black Harrier	*Circus maurus*	Fynbos, Grass	EN	VU	**-39.21**	-0.186	0.38	**-41.01**	**-36.14**	-0.441	550	236925	515403	52731	2.31
Protea Seedeater *	*Crithagra leucoptera*	Fynbos	LC	LC	**-46.47**	-0.173	0.37	-23.75	-10.61	**-0.979**	22	44469	69255	8829	1.97
Cape Rockjumper *	*Chaetops frenatus*	Fynbos	NT	LC	**-53.39**	-0.165	0.39	-25.00	-19.15	-0.837	57	30618	48843	5913	1.7
Rudd's Lark *	*Heteromirafra ruddi*	Grass	EN	VU	**-50.07**	-0.162	0.46	**-40.00**	-14.29	-0.303	26	**4374**	**10935**	**1053**	**1.13**
Sclater's Lark	*Spizocorys sclateri*	Karoo	NT	NT	-15.38	-0.153	0.43	**-42.86**	**-41.18**	0.124	20	**16767**	64152	3240	1.58
Grey-winged Francolin	*Scleroptila africana*	Grass, Fynbos	LC	LC	**-39.02**	-0.150	0.35	-23.74	-20.58	**-0.930**	435	264627	419904	60912	2.85
Black-eared Sparrow-lark	*Eremopterix australis*	Karoo	LC	LC	-17.01	-0.143	0.42	**-40.91**	**-39.18**	-0.120	14	86751	267543	17739	2.54
Black-headed Canary	*Serinus alario*	Karoo	LC	LC	-24.03	-0.141	0.34	**-30.12**	-27.96	-0.392	12	268272	532170	68202	3.02
Fairy Flycatcher	*Stenostira scita*	Karoo	LC	LC	-13.79	-0.134	0.37	**-31.01**	-27.03	-0.322	6	424278	767637	115668	2.85

Cape Rock Thrush	*Monticola rupestris*	Generalist	LC	LC	-23.29	-0.117	0.33	-20.89	-16.92	-0.588	58	333882	487701	91368	2.85
Knysna Turaco	*Tauraco corythaix*	Forest	LC	LC	-26.21	-0.113	0.32	-22.31	-20.35	-0.502	310	134136	213597	47871	2.56
Swee Waxbill	*Coccopygia melanotis*	Generalist	LC	LC	-25.22	-0.111	0.37	-22.98	-17.70	-0.275	6.5	212868	341901	62289	2.47
Cinnamon-breasted Warbler	*Euryptila subcinnamomea*	Karoo	LC	LC	14.27	-0.100	0.45	**-31.25**	-25.42	-0.050	12	32805	76545	5427	**1.09**
Pied Starling	*Lamprotornis bicolor*	Karoo	LC	LC	-19.02	-0.099	0.24	-11.79	-10.93	**-1.068**	104	706401	893754	337851	3.62
Blue Korhaan	*Eupodotis caerulescens*	Grass	LC	NT	-17.60	-0.097	0.31	-18.37	-15.74	-0.482	1300	206307	284310	71361	3.37
Chorister Robin-Chat	*Cossypha dichroa*	Forest	LC	LC	-24.73	-0.092	0.34	-21.20	-17.35	-0.400	46	123201	183708	32724	2.29
Cape Siskin *	*Crithagra totta*	Fynbos	LC	LC	-18.16	-0.090	0.31	-15.00	-5.83	-0.398	13	83835	106434	28107	2.65
Orange-breasted Sunbird *	*Anthobaphes violacea*	Fynbos	LC	LC	-17.28	-0.081	0.29	-9.93	-7.35	-0.674	9	97686	115911	35316	2.87
Yellow-breasted Pipit *	*Anthus chloris*	Grass	VU	VU	-4.44	-0.074	0.44	-21.43	7.14	0.107	25	24057	45198	4617	**1.39**
Karoo Eremomela	*Eremomela gregalis*	Karoo	LC	LC	8.52	-0.074	0.41	-21.56	-18.35	-0.142	8	99144	204120	19926	2.29
Jackal Buzzard	*Buteo rufofuscus*	Generalist	LC	LC	-7.09	-0.072	0.32	-17.43	-15.34	-0.013	1340	713691	1043199	280179	3.26
Grey Tit	*Parus afer*	Karoo	LC	LC	-4.69	-0.067	0.35	-14.11	-12.00	-0.340	20	262440	411156	63747	3.13
Sickle-winged Chat	*Cercomela sinuate*	Karoo	LC	LC	-0.67	-0.066	0.38	-17.49	-13.85	-0.086	19	298890	500094	66501	2.74
Cape Sugarbird *	*Promerops cafer*	Fynbos	LC	LC	-7.87	-0.065	0.30	-11.38	-5.16	-0.425	35	105705	128304	44469	2.91
Forest Canary	*Crithagra scotops*	Forest	LC	LC	-14.02	-0.062	0.34	-14.80	-9.80	-0.097	15	137052	190998	40986	2.31
Namaqua Warbler	*Phragmacia substriata*	Karoo	LC	LC	-11.44	-0.057	0.36	-12.61	-11.69	-0.206	12	214326	312741	51840	2.65
Buff-streaked Chat	*Campicoloides bifasciata*	Grass	LC	LC	-3.98	-0.055	0.35	-16.59	-13.93	-0.090	35	131949	189540	44388	2.76
Forest Buzzard	*Buteo trizonatus*	Forest	LC	LC	-7.15	-0.040	0.39	-13.92	-3.05	0.118	660	98415	142884	27135	1.92
Southern Double-collared Sunbird	*Cinnyris chalybeus*	Generalist	LC	LC	4.20	-0.037	0.29	-11.23	-9.73	0.037	8	421362	558414	183222	3.09
South African Cliff Swallow	*Petrochelidon spilodera*	Generalist	LC	LC	12.09	-0.035	0.34	-15.81	-10.82	0.329	21	359397	523422	158355	2.89
Cape Weaver	*Ploceus capensis*	Generalist	LC	LC	8.14	-0.025	0.29	-7.28	-6.24	0.113	46	613818	769824	279531	3.23
Drakensberg Siskin	*Crithagra symonsi*	Grass	LC	LC	16.96	-0.022	0.36	-5.00	2.78	0.137	13	29889	43011	5832	2.64
Bush Blackcap	*Lioptilus nigricapillus*	Grass, Forest	VU	NT	-19.52	-0.019	0.43	-6.25	11.11	0.206	31	54675	87480	10368	1.54
Large-billed Lark	*Galerida magnirostris*	Karoo	LC	LC	8.59	-0.017	0.32	-8.79	-7.77	0.210	45	401679	564246	132192	3.44
Southern Tchagra	*Tchagra tchagra*	Thicket	LC	LC	2.51	-0.017	0.34	-9.35	-6.57	0.196	47	201204	264627	64638	2.85
African Rock Pipit	*Anthus crenatus*	Grass	NT	LC	36.65	-0.014	0.40	-12.81	-8.22	0.265	31	156735	250776	33858	2.3
Greater Double-collared Sunbird	*Cinnyris afer*	Generalist	LC	LC	9.74	-0.010	0.31	-6.35	-3.46	0.213	12.5	331695	412614	132597	3.02
Fiscal Flycatcher	*Sigelus silens*	Generalist	LC	LC	13.17	-0.008	0.28	-7.58	-6.21	0.357	26	858762	1071630	395928	3.38
Layard's Tit-Babbler	*Sylvia layardi*	Karoo	LC	LC	32.15	-0.005	0.39	-8.79	-4.96	0.229	15	282852	460728	68769	2.68
Barratt's Warbler	*Bradypterus barratti*	Grass	LC	LC	1.51	-0.004	0.39	-10.56	-3.57	0.384	19	91125	134865	20736	2.13

Brown Scrub Robin	*Erythropygia signata*	Forest	LC	LC	8.69	0.003	0.35	-6.19	7.95	0.362	38	75816	97686	18387	1.84
Cape Spurfowl	*Pternistis capensis*	Generalist	LC	LC	8.29	0.007	0.27	-4.27	-3.49	0.332	820	161838	195372	82215	2.93
Karoo Lark	*Calendulauda albescens*	Karoo	LC	LC	36.91	0.010	0.36	-2.09	0.44	0.168	29	176418	250047	49329	3.12
Knysna Warbler *	*Bradypterus sylvaticus*	Forest	VU	VU	50.20	0.027	0.41	-2.33	5.26	0.836	21	30618	41553	6399	**1.47**
Southern Bald Ibis	*Geronticus calvus*	Grass	VU	VU	-1.38	0.030	0.33	4.44	7.76	0.095	1100	188811	225990	72171	3.34
Cape Grassbird	*Sphenoeacus afer*	Grass, Fynbos	LC	LC	37.97	0.047	0.33	-3.19	-0.20	0.848	30	371061	464373	156006	2.96
Victorin's Warbler *	*Cryptillas victorini*	Fynbos	LC	LC	12.09	0.049	0.35	1.47	4.84	0.377	19	50301	61236	14256	2.22
Mountain Pipit	*Anthus hoeschi*	Grass	NT	LC	100.99	0.049	0.40	-8.70	0.00	0.596	27	**16767**	26244	2106	2.22
Melodious Lark	*Mirafra cheniana*	Grass	LC	NT	63.12	0.050	0.42	4.43	13.18	0.443	20	120285	174960	29160	2.33
Cape Bulbul *	*Pycnonotus capensis*	Generalist	LC	LC	27.22	0.065	0.22	0.72	1.09	1.189	39	199746	219429	115992	3.18
Cloud Cisticola	*Cisticola textrix*	Grass	LC	LC	93.66	0.073	0.35	-5.79	-1.48	1.063	9	414072	518319	173745	3.06
Red Lark *	*Calendulauda burra*	Desert	VU	VU	140.84	0.084	0.43	5.56	11.76	1.063	37	**16767**	41553	4455	2.09
Knysna Woodpecker *	*Campethera notata*	Forest, Thicket	NT	NT	107.12	0.126	0.34	1.64	4.50	1.741	62	87480	106434	26487	2.45

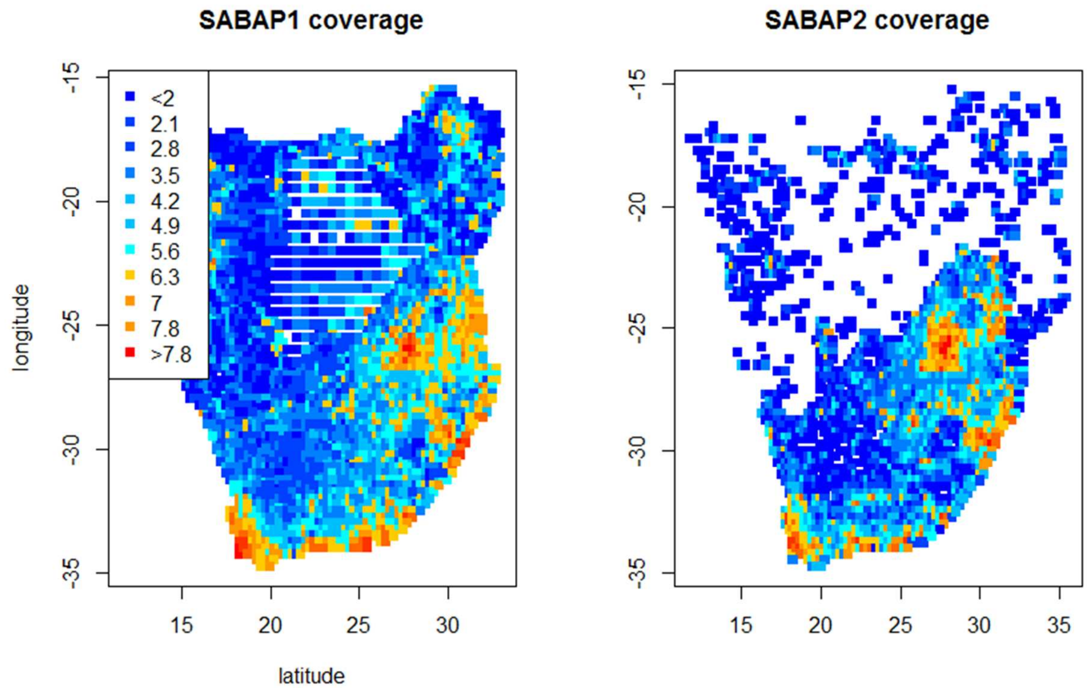

Figure 1: Area and intensity of coverage during the two atlas periods. Colours represent log of number of lists reported for each grid cell, with red high and blue low. SABAP2 coverage is shown to 30 May 2014, as the project is ongoing.

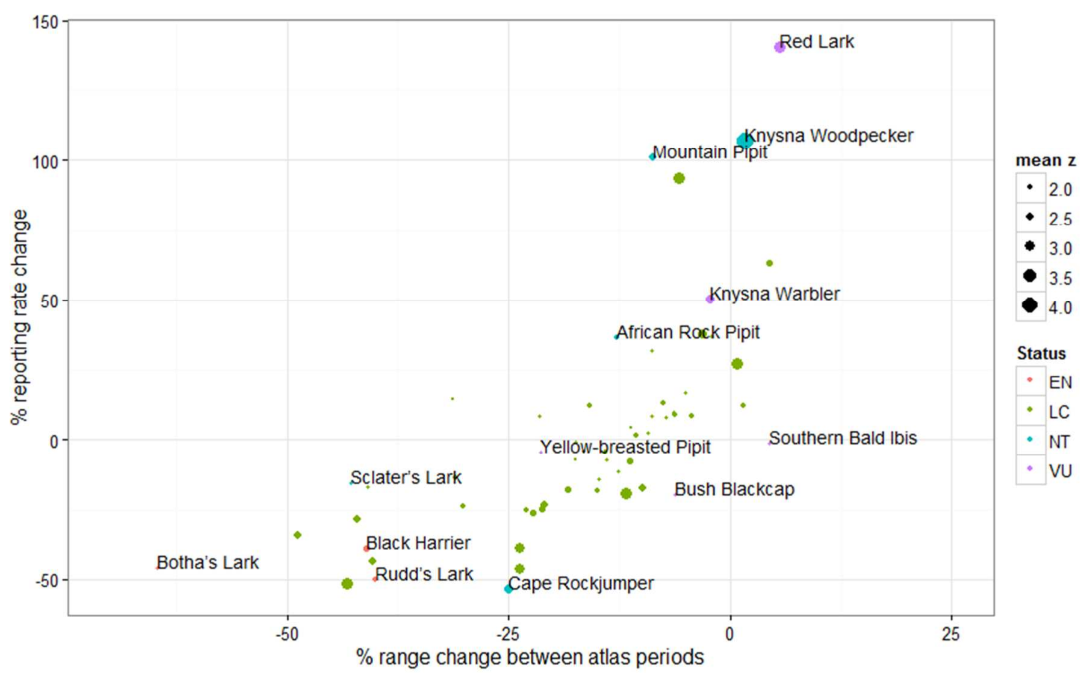

Figure 2: Reporting rate change for 58 South African endemic bird species plotted against change in reported range between SABAP1 and SABAP2. Named species have threatened status: Endangered (red), Near Threatened (blue), Vulnerable (purple). Green dots are species without threatened status (Least Concern). Point size represents the absolute value of the mean z-score.

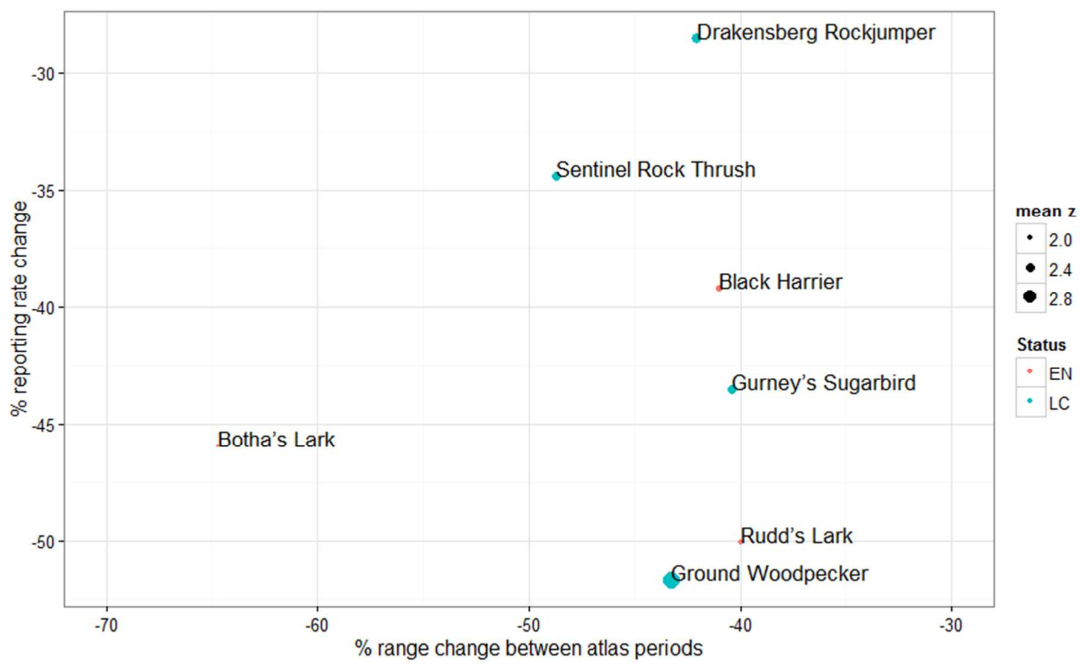

Figure 3: Reporting rate change for seven South African endemic bird species plotted against change in range between SABAP1 and SABAP2. This figure shows the lower left hand corner of Figure 2 in more detail - species qualifying as those of conservation concern due to range and population decrease. Size of the points is weighted by mean z-score.

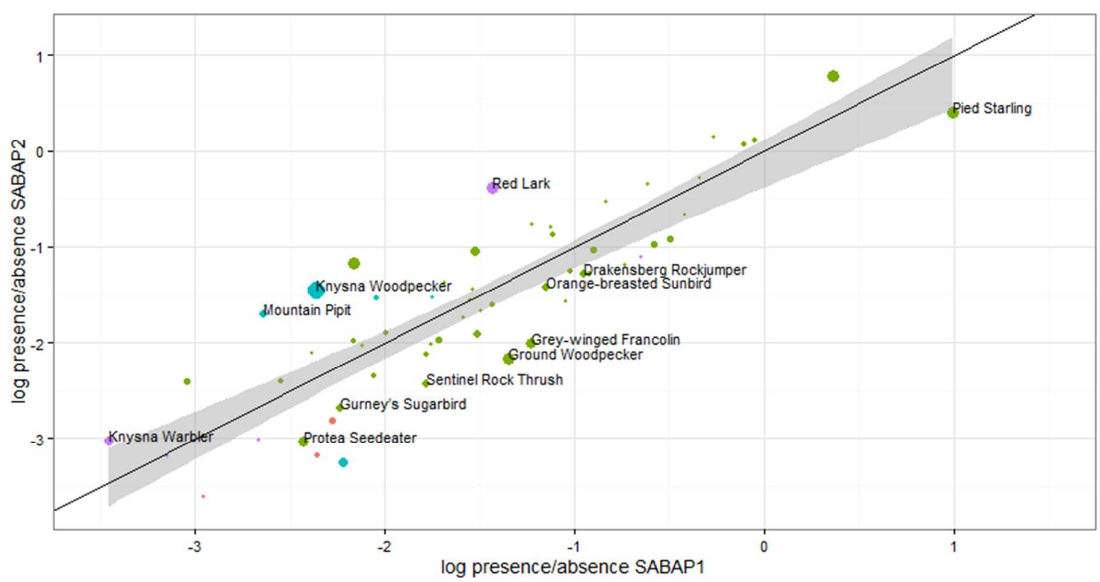

Figure 4: Presence/absence ratios for 58 endemic bird species for each atlas period. Species on the negative end of the x-axis are generally infrequently reported, while those on the positive side are commonly reported: negative values indicate species reported from less than 50% of cells. Shading represents the 95% confidence interval of the regression between the values on the two axes.

Species below the 1:1 line (black diagonal) are species reported less frequently in SABAP2. Selected species classified as Least Concern with a lower reporting rate in SABAP2 are labelled, as are selected species with threatened status with higher reporting rates in SABAP2.

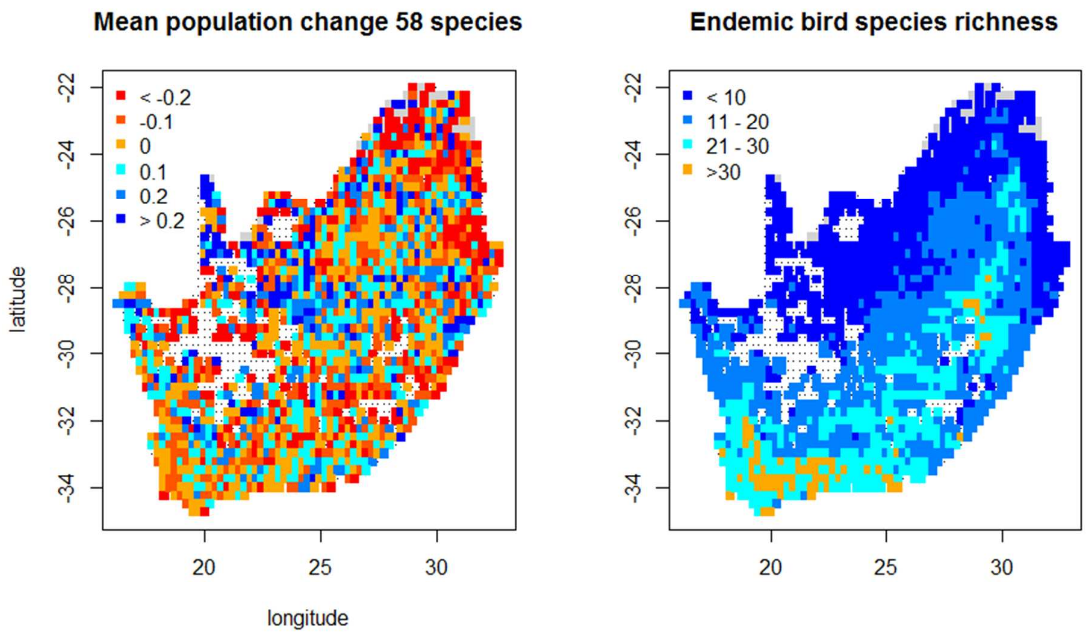

Figure 5: Mean population change across all species within each grid cell (left panel). N for each grid cell is indicated by endemic species richness (right panel). Grids not included in this analysis due to insufficient coverage (<2 lists for both atlas periods) are white with black points.

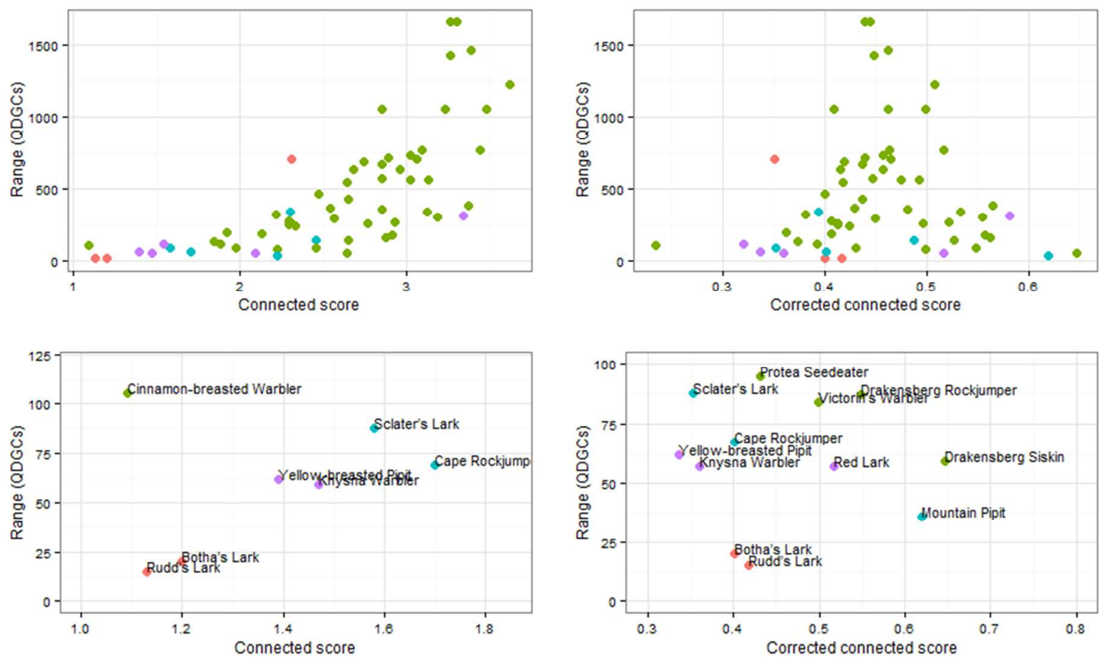

Figure 6: Connectivity (left-hand panels) and corrected connectivity (connected score/log(range); right hand panels) for southern African endemic bird species. The lower two charts are the lower left sections of the upper charts, indicating species with small ranges and low connectivity; QDGC = quarter degree grid cells.