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*CORRESPONDENCE
Karis A. Daniel
dnlkar006@myuct.ac.za

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Bird atlas in action: using citizen science data to generate population trend alerts in Hessequa, South Africa

Karis A. Daniel[1*], Les G. Underhill[1,2] and Johan A. van Rooyen[3]

[1]Department of Biological Sciences, University of Cape Town, Cape Town, South Africa, [2]Biodiversity and Development Institute, Cape Town, South Africa, [3]University of the Third Age (U3A) Stilbaai Bird Group, Stilbaai, South Africa

Citizen science data are rapidly transforming the conservation landscape. Targeted participatory citizen science initiatives generate nuanced data capable of monitoring trends in populations and generating early warnings for species and habitats experiencing significant declines. In the Hessequa Atlasing Area, Western Cape, South Africa, citizen science 'atlasers' involved with the Second Southern African Bird Atlas Project (SABAP2) have worked with scientific leadership since 2014 to improve the quality of bird atlas data in their region for species monitoring. In this study, we used reporting rates from SABAP2 checklists in the Hessequa Atlasing Area to calculate changes in range size and relative abundance for the 165 most commonly reported species in the region. We used a seven-tier alert system and broad habitat categories to sort species by priority for conservation action. Our results showed that wetland and marine associated species are experiencing the greatest declines in range and relative abundance in the Hessequa Atlasing Area, whilst urban and grassland associated species are largely increasing. We discuss how observed changes in populations may be used to guide conservation action and provide recommendations for scientists and non-scientific community members on engaging with and responding to the changes highlighted in each of the seven alert levels provided.

KEYWORDS

bird atlas, reporting rates, citizen science, early warning system, SABAP2, species monitoring

1 Introduction

Conservation is facing a 'wicked' problem (Sharman and Mlambo, 2012). Biodiversity loss, the extinction of species and ecological interactions, threatens the integrity and functioning of populations and ecosystems, both human and non-human, globally (Díaz et al., 2019; Hochkirch et al., 2021; CBD, 2022; Isbell et al., 2023). Conservation scientists are asked to advise and implement strategies to mitigate losses, but are faced with data gaps and biases that impede effective action (Jetz et al., 2011; Chambers et al., 2016; Parsons, 2016; Proença et al., 2017). Recent research has called for improved monitoring efforts to address data gaps, prioritise focus, and strengthen conservation measures (Proença et al., 2017; Siddig, 2019); a potential solution may lie in the field of citizen science. Through collecting large quantities of species data at vast geographic scales and often from under-sampled regions, citizen scientists may contribute towards the population monitoring needed to mitigate the current biodiversity crisis.

Crucially, citizen science data may support the development of early warning systems. These systems are often constructed with the goal of disaster risk management, i.e., floods, landslides, or drought; however, in the long term, biodiversity loss may be considered a disaster of equal if not greater magnitude than any natural disaster (Barnard et al., 2017). In the context of species conservation, early warning systems may be broadly described as monitoring schema implemented with the goal of detecting significant changes among species, populations, and habitats (Jetz et al., 2019). In conservation, warning systems are already widely utilised; however, many of these are retrospective rather than prospective (Schmeller et al. (2018). For instance, the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (2022) has been used internationally to raise awareness, prioritise conservation intervention, incentivise funding, and inform management and policy decisions for over 50 years (Betts et al., 2020). Although crucial, IUCN assessments occur at long intervals, and are thus likely to detect patterns late rather than early, because assessments are based on changes that have already occurred. These classifications also tend to bias interventions towards rare species and those with a high immediate extinction risk (Luther et al., 2016; Baker et al., 2018; Christie et al., 2020), potentially missing common species and species experiencing moderate to slow declines, and overlooking the importance of preventing common species from becoming rare (e.g. Dirzo et al., 2014; Ceballos et al., 2017; Weeks et al., 2022). The value of an early warning system lies in its ability to inform proactive rather than remedial conservation measures, enabling thorough evaluation and strategic response instead of rapid and reactive short-term solutions (Luther et al., 2016; Schmeller et al., 2018). Schmeller et al. (2018) identify eight biodiversity variables essential to early detection which include, among others, abundance, ecosystem heterogeneity, and range dynamics. Some recently trialled systems have focused on early detection by monitoring specific biomes, i.e. tropical rainforests (Rovero and Ahumada, 2017), or implementing warning systems for low genetic diversity among indicator species in threatened habitats (Zimmerman et al., 2022), but for many taxa, particularly in the Global South, these baseline data are either scarce (Boakes et al., 2010; Feeley et al., 2016; Hoveka et al., 2020; Oliver et al., 2021; von der Heyden, 2022), or are collected and housed by non-local institutions in first-world nations (Cresswell, 2018; Stephenson and Stengel, 2020; Asase et al., 2021; de Vos, 2022; Miller et al., 2023). Citizen science offers an opportunity to collect and interpret baseline data at a regional scale, and thus is gaining traction as a facilitator of localised monitoring systems in the Global South (Gossa et al., 2015; State of India's Birds [SoIB], 2020; Asase et al., 2021; Cyvin, 2022).

To date, citizen science project data have supported early warning systems for several taxa internationally, including butterflies (Stenoien et al., 2018), plants (García et al., 2021), fish (Poursanidis and Zenetos, 2013; Giovos et al., 2019), and microalgae (Hardison et al., 2019). The involvement of citizen scientists in maintaining these systems has led to the development of a new term, the participatory early warning system (e.g. Marchezini et al., 2018), referring to ground-level engagement of community members in collecting data that ultimately contribute towards the wellbeing of their immediate surroundings. In 2005, The United Nations together with the World Conference on Disaster Reduction adopted the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" as a set of strategic guidelines for detecting and mitigating the impacts of natural disasters. The framework emphasised the importance of "early warning systems that are people centred, in particular systems whose warnings are timely and understandable to those at risk (…) including guidance on how to act upon warnings" (UNISDR, 2005, para. 17, ii.d.9). In addition to engaging the general public in conservation, participatory systems also support a decentralised conservation narrative by encouraging collaboration, data collection, and communication with and within local scientific communities (Asase et al., 2021).

While participatory early warning systems do carry important social significance, to be effective as warning tools, data collection must be rigorous enough to meet both scientific standards and established monitoring targets. Within southern Africa, multiple citizen science projects already contribute to conservation decision-making (Barnes, 1998; Barnes, 2000; Robertson et al., 2010; Barnard et al., 2017); still, the role of citizen science data in informing early warning systems in southern Africa remains largely unexplored within scientific literature (Chambers et al., 2016). Several projects hold potential to strike the necessary balance between supporting a participatory early warning system and collecting meaningful data, and perhaps the strongest candidate is the Second Southern African Bird Atlas Project (SABAP2), a long-term citizen science initiative launched in 2007. Crucially from a data science perspective, SABAP2 offers a historically robust and consistently updated dataset for analysis (Underhill et al., 2017; Lee et al., 2022).

Although the quality of citizen science data is often called into question (e.g. Bird et al., 2014; Kamp et al., 2016; Johnston et al., 2021), the SABAP2 protocol is designed to mitigate the effects of spatial and observer bias by restricting participation to skilled birders and using gamification to encourage participants to both atlas in their 'home' region and visit regions with poor coverage (Ainsley and Underhill, 2017; Underhill et al., 2017; Brown and Williams, 2019; Daniel and Underhill, 2023). As noted by Johnston et al. (2021), the statistical strength of citizen science data is improved by using comprehensive checklists which require participants to list every species they encounter. SABAP2 employs a strict data collection protocol in which observers work in grid cells of 5×5 minutes latitude by longitude (pentads), spending two or more hours visiting as many habitat types as possible in the pentad and compiling a complete species checklist, thus enabling scientists to infer the pseudo-absence of non-detected species. The temporal dimensions of SABAP2 data quality have also been tested; coordinated systematic atlasing efforts have been demonstrated to provide nuanced and up-to-date representations of species presence (Daniel and Underhill, 2023).

The quality of SABAP2 data has been substantiated, yet it remains to be seen how these data may inform conservation action at the species level. Can SABAP2 data generate meaningful early warnings for populations, and if so, how might they then facilitate intervention? Trends in SABAP2 data are readily detected via reporting rates: the proportion of checklists on which a species is recorded in a grid cell (Harrison and Underhill, 1997). Although some seasonal and interannual variation of reporting rates is expected, sharp or continued increase or decline may indicate an underlying problem. Identifying potential aberrances early through monitoring allows scientists and policy makers to carefully assess the situation, taking into consideration any environmental or anthropogenic changes which may correspond with or contribute to the population change, and act accordingly.

In this study, we tested the ability of systematically collected SABAP2 data from the Hessequa Atlasing Area, South Africa, to detect significant trends in populations of 165 locally common avian species. Using changes in range and relative abundance calculated from reporting rates, we sorted species into seven alert categories for early warnings, and searched for patterns between alert categories and species habitat preferences. We discuss the broader significance of the patterns we detected, including how warnings for these species may be utilised to trigger effective response. Finally, we discuss the broader social impacts of implementing a participatory warning system, and provide recommendations for employing citizen science projects as conservation tools for generating early warnings and enabling thoughtful social engagement.

2 Methods

Generating citizen science data for modelling often requires compromising data quality (i.e. temporal proximity, observer expertise, standardised protocol) in favour of quantity (Isaac et al., 2014; Daniel and Underhill, 2023). Ensuring that species records are current, accurate, and collected systematically is more time-intensive and requires more specialised skills than opportunistic data collection (Boersch-Supan et al., 2019). SABAP2 was designed jointly by a team of biologists and statisticians to maximise both data quantity and quality, implementing a strict protocol to improve data integrity whilst operating at a geographic scale which feasibly allows for complete regional coverage by local citizen science participants (Underhill et al., 2017). We used reporting rates from SABAP2 checklists collected as part of a trialled monitoring scheme to calculate changes in the range and relative abundance of species in the Hessequa Atlasing Area, our region of interest.

2.1 Reporting rates as a monitoring tool

Detecting trends in species populations requires a tool sensitive enough to detect subtle shifts, and blunt enough to characterise large changes. For SABAP2 data, reporting rates offer a suitable starting point. The reporting rate for a species is defined as the proportion of checklists on which it has been recorded; the concept dates back to Linsdale (1928), who intuited that reporting rate would provide an index of abundance. Following Linsdale's work, the next important quantitative development was made by Temple and Temple (1984, 1986), who showed that where both count data and reporting rates were available, these two measures were closely correlated using Spearman's rank correlation coefficient. The use of this measure of correlation demonstrates an understanding of the reality that reporting rates are monotonically related to abundance, and the relationship is not linear (Underhill et al., 1992). This concept was further advanced by Griffioen (2001), who recognised that mathematical ecology developed by Nachman (1981) could be applied to the relationship between abundance, denoted by N, and reporting rate R. Using data originating in the Australian Bird Count project (Ambrose, 1991), he demonstrated that the relationship between the $\log(N)$ and $\log(-\log(1-R))$ was linear. The theoretical implications of Griffioen's (2001) results are explored in Underhill (submitted).

Although straightforward, the use of reporting rates to measure population trends is not without risk. Potential biases inherent within the data invariably challenge the validity of results. SABAP2 was preceded by another atlas project, SABAP1, with a more relaxed protocol and coarser spatial and temporal resolutions (Underhill et al., 1992; Harrison et al., 1997). While reporting rates from SABAP1 did generally reflect estimates of actual abundance, inconsistencies in sampling effort were an accompanying caveat to utilising the data in this way (Robertson et al., 1995). The problem of observer effort remains a contemporary concern in any atlas data analysis (e.g. Szabo et al., 2010; Huntley et al., 2012; Szabo et al., 2012), along with seasonal and behavioural variations in the conspicuousness of a species and potential misidentifications by observers (Harrison and Underhill, 1997).

Robertson et al. (2010) list seven qualities which should ideally characterise a data-strong atlas project: A spatial scale appropriate to the study taxon; the highest possible spatial and temporal resolution; the highest possible taxonomic resolution (e.g. species level identifications rather than family level); the highest possible demographic resolution (e.g. inclusive of life stage and age information); a standardised protocol with a reliable indication of sampling effort; a well-described sampling protocol; and the greatest possible number of unique sampling units (e.g. pentads). Several of these components were already included in SABAP1, and either carried over or were introduced into SABAP2. The spatial resolution of the project was increased from quarter-degree units of 15×15 minutes latitude by longitude to the pentad (5×5 minutes latitude by longitude), and the temporal resolution increased from a monthly to a five-day interval. By introducing a minimum 2-hour atlasing protocol, SABAP2 reduced the uncertainty surrounding sampling effort. To minimise the chances of missing inconspicuous or seasonally gregarious species, a dimension of thoroughness was added to the sampling protocol by requiring 'atlasers' to visit as many habitat types as possible within each pentad. Finally, to address the problem of misidentification, new SABAP2 checklists are vetted automatically against existing records for the region, and panels of regional identification experts are tasked with reviewing incoming checklists and querying unusual records (Brooks et al., 2022). While the precautions built into SABAP2 certainly do not eliminate bias, they are designed to minimise its presence in checklists; thus, SABAP2 reporting rates can be considered a reasonably robust metric for monitoring avian population trends (e.g. Lee et al., 2017).

2.2 The Hessequa Atlasing Area and monitoring effort

Although SABAP2 data quality is strong overall, its weakness is temporal quality. Data are not collected at the regular intervals necessary for biodiversity monitoring. This is true of many large-scale citizen science initiatives (e.g. Kelling et al., 2015); checklists remain opportunistic, meaning there is no guarantee that a pentad will be atlased with any regularity. This challenges the utility of SABAP2 as a monitoring tool, since old checklists for a pentad may not provide accurate representations of the species currently within the pentad, and inconsistent sampling diminishes the ability to detect reliable population trends for individual species (Daniel and Underhill, 2023). In 2014, citizen science participants in the Hessequa Atlasing Area, a region within the Western Cape, South Africa, collaborated with leading scientists to implement a seasonal data collection strategy, ongoing as of January 2023 (van Rooyen, 2018; van Rooyen and Underhill, 2020). Collection efforts were designed with the intention of generating data of sufficient temporal quality for use in monitoring; three complete monitoring cycles (2014–2017, 2018–2019 and 2020–2021) were available for detecting trends in regional populations at the time of this study.

The Hessequa Atlasing Area (Hessequa) is a region comprising 75 pentads within the Western Cape, South Africa. The region lies in the Hessequa Municipality and is bordered to the north and south respectively by the Langeberg Mountains and the sea. Although Hessequa contains some patches of natural vegetation, particularly in the mountains and along the coast, most of the region is agriculturally transformed with land used for both livestock farming (cattle and sheep) and crop production (barley, canola and wheat) (van Rooyen and Underhill, 2020).

In 2014, atlasers in Hessequa joined forces with scientific leadership at the University of Cape Town to launch a regional-scale monitoring project. From 2014 until December 2017, each pentad in Hessequa was atlased at least once per year, and twice per year in 2016 and 2017. From 2017 onwards, the project ran in two-year cycles, dividing Hessequa into a chessboard pattern for the four austral seasons (van Rooyen, 2018; van Rooyen and Underhill, 2020; Daniel and Underhill, 2023). Over each subsequent two-year cycle, half of the pentads in the region were visited for fieldwork in summer and winter during year one, and autumn and spring during year two. The remaining pentads received fieldwork in autumn and spring during year one, and summer and winter during year two. Thus, following a standard two-year cycle, every pentad in Hessequa was visited at least once in each season. Fieldwork was ongoing as of December 2022.

2.3 Generating rapid alerts using systematic bird atlas data

When considering how to use reporting rates in generating early warning systems, it is convenient to classify species of interest into alert categories based on one or more criteria (i.e. increasing/decreasing range, distribution, abundance) to aid in the communication of results. At the regional and national level, these categorisations also serve as valuable tools for comparison against larger international classification schema such as the IUCN Red List (2022), providing a deeper understanding of the status of species within a geographic region (e.g. Jiang et al., 2020). The criteria, however, are not hard categories; they fall along a continuum, and the boundaries for categories can be adjusted. In this study, we use seven categories (Table 1): large decrease in range (red); large decrease in relative abundance (amber); moderate decrease in relative abundance (yellow); stable relative abundance (green); moderate to large increase in relative abundance of ecologically neutral or positive species (blue); moderate to large increase in either range or relative abundance of ecologically negative species (e.g. alien species and agricultural pests) (purple); and moderate to large increase in range of ecologically neutral or positive species (pink). The final two categories were included for contextual relevance. Many pentads in Hessequa encompass privately owned farmland, and because our aim was to generate practical recommendations for the region, we elected to distinguish species which may be of particular relevance to local landowners.

TABLE 1 Seven alert level categories for species populations based on changes in range and relative abundance.

Alert	Description	Criteria
Red	Large decrease in species range	Decrease of 30% or more in range
Amber	Large decrease in species relative abundance	Decrease of 30% or more in relative abundance
Yellow	Moderate decrease in species relative abundance	Decrease of 11–29% in relative abundance
Green	Stable species relative abundance	10% decrease–10% increase in relative abundance
Blue	Moderate to large increase in relative abundance of ecologically neutral or positive species	Increase of 11% or more in relative abundance
Purple	Moderate to large increase in either range or relative abundance of ecologically negative species	Increase of 11% or more in range or relative abundance
Pink	Moderate to large increase in range of ecologically neutral or positive species	Increase of 11% or more in range

2.4 Selecting species of interest and characterising changes

In the interest of providing actionable information, we focused on species for which mitigation measures could realistically be achieved in the region (i.e. the most commonly occurring species). Thus, rare species (species with low reporting rates) are excluded from this analysis: we chose a cut-off reporting rate of 5%. This reporting rate was calculated over the Hessequa Atlasing Area for the entire study period 2014–2021. Although 5% may well represent an overly inclusive low limit, we chose to err on the side of caution and therefore anticipate that some species included in this analysis will be evaluated as "too rare" in the study area to warrant an alert, or for subsequent intervention to be meaningful.

Having selected the species of interest, we calculated the two main criteria needed to classify species into categories: Change in range, and change in relative abundance. For change in range, we calculated the numbers of pentads occupied by each species in the three time periods 2014–2017, 2018–2019 and 2020–2021. For the sake of brevity, in this paper, we only present results based on a comparison of ratios between the first and third time periods (2014–2017 and 2020–2021). We could have also compared the first to second or second to third time period reporting rates, and indeed, in a workshop regarding mitigative actions in response to atlas data, these results would be considered. As the period for which data from systematic atlasing gets longer, it will be feasible to examine trends and evaluate which species are characterised by large increases and decreases in abundance (i.e. the species which are prone to irruptions) and for which short term changes in reporting rates represent statistical 'noise' and not 'signal.' Given the relatively short study period, we did not *a priori* expect many, or even any, species to display large changes in range size; rather, we included this category for the sake of completeness. Decreases in range size are widely considered positive correlates of increased extinction risk for a species (Mace et al., 2008; Gaston and Fuller, 2009; Lee and Jetz, 2010; Staude et al., 2019), though only one among a complex suite of species-specific contributors (Orme et al., 2006; Cardillo et al., 2008; Chichorro et al., 2019; Hernández-Yáñez et al., 2022). A few studies have examined the relationship between range decrease and species declines among birds (e.g. Lee and Jetz, 2010); however, birds constitute a challenging taxon since many species are migratory, nomadic, or semi-nomadic in response to weather events (Runge et al., 2015). While a significant and persistent change in range may indeed reflect, for instance, species decline, slight and variable changes cannot be considered reliable indicators of population trends. In these cases, a more sensitive tool such as relative abundance is often used as a complementary metric to better characterise population trends (Lawton, 1993; McGill and Collins, 2003; Huntley et al., 2012).

For species which showed negligible to moderate changes in range (0–29% increase or decrease), we estimated changes in relative abundance. To determine changes in relative abundance, we found the set of pentads in which each selected species had been recorded during the study period, i.e. the range of the species within the Hessequa Atlasing Area. For each of these pentads, we calculated C, the change in relative abundance, as described by Underhill (submitted).

$$C = \log(1 - R_2)/\log(1 - R_1),$$

where R_1 is the reporting rate for the species in the grid cell for the first period of interest, and R_2 is the reporting rate for the second period. We calculated the value of C for each pentad in the range, and summarised the value by calculating the median. To avoid a logarithm of zero, we changed the value of reporting rates of 0 and 1 to 0.01 and 0.99 respectively (because the summary statistic is the median, this does not impact results).

Finally, we classified each of the species of interest by habitat association, adapting the broad categories described by Chittenden et al. (2018). Species were categorised based on habitat preferences as Marine, Wetland, Thicket, Forest, Grassland, Fynbos, Urban, Montane, or Generalist. Species associated with more than one habitat were counted in all relevant habitat types; for example, Pied Kingfisher was counted as both a Wetland and a Marine species. Habitat categories were kept broad to encompass a variety of habitat sub-types. Thus, Marine included coastal habitat, Grassland included agricultural fields and Urban included suburban areas and gardens.

3 Results

A total of 1,951 checklists were submitted to the SABAP2 project for the Hessequa Atlasing Area between 2014 and 2021, containing a total of 109,273 records of species distribution. They represented a total of 323 species, of which 165 had reporting rates exceeding 5% for the time period.

3.1 Species experiencing greatest declines: Red, Amber and Yellow Alerts

Of the 165 species with reporting rates exceeding 5%, 23 species showed range declines exceeding 30%, and were thus categorised as Red Alerts (Table 2). Among these, six species showed range declines exceeding 50%, and four of these were Wetland associated.

Of the 132 species whose changes in range were moderate to negligible, 29 species showed decreases in relative abundance exceeding 30% (Table 2); these were assigned an Amber Alert. 26 species showed decreases in relative abundance between 11–29%, and were assigned a Yellow Alert.

By habitat preference, most species in the Red and Amber Alert categories were Grassland, Urban, and Wetland associated. However, these categories also contained the largest proportion of Marine (17 species) and Wetland (51) species. Of the 23 Red alert species, 14 were associated with Wetlands, five with Marine, and five with Forest habitat (Table 2; Figure 1). Wetland associated

TABLE 2 Range and relative abundance changes for the 165 species in the Hessequa Atlasing Area with reporting rates exceeding 5%.

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
Red	*Calidris minuta*	Little Stint	Wetland	-70.0	-95.4
	Nycticorax nycticorax	Black-crowned Night-Heron	Wetland	-64.7	-91.0
	Indicator minor	Lesser Honeyguide	Forest	-60.0	-91.5
	Zapornia flavirostra	Black Crake	Wetland	-59.1	-93.0
	Tringa nebularia	Common Greenshank	Wetland	-58.1	-93.5
	Ciconia ciconia	White Stork	Grassland	-54.1	-93.0
	Muscicapa adusta	African Dusky Flycatcher	Forest	-48.4	-94.5
	Tachymarptis melba	Alpine Swift	Grassland	-48.1	-94.9
	Corythornis cristatus	Malachite Kingfisher	Wetland	-47.5	-92.5
	Phyllastrephus terrestris	Terrestrial Brownbul (Bulbul)	Forest, Thicket	-45.2	-93.5
	Charadrius hiaticula	Common Ringed Plover	Marine	-41.7	-92.5
	Morus capensis	Cape Gannet	Marine	-41.7	-46.9
	Circus maurus	Black Harrier	Fynbos, Grassland	-41.5	-92.5
	Scopus umbrette	Hamerkop	Wetland	-40.7	-94.5
	Ceryle rudis	Pied Kingfisher	Wetland, Marine	-38.5	-95.2
	Chrysococcx caprius	Dideric (Diederik) Cuckoo	Forest, Urban	-33.3	-11.8
	Centropus burchellii	Burchell's Coucal	Forest, Urban, Wetland	-33.3	-66.0
	Himantopus himantopus	Black-winged Stilt	Wetland	-32.4	-50.0
	Gallinula chloropus	Common Moorhen	Wetland	-31.8	-50.4
	Megaceryle maxima	Giant Kingfisher	Wetland, Marine	-31.3	-93.5
	Spatula smithii	Cape Shoveler	Wetland	-31.0	-7.8
	Charadrius marginatus	White-fronted Plover	Wetland, Marine	-30.8	14.8
	Platalea alba	African Spoonbill	Wetland	-29.5	-14.0
Amber	*Bradypterus sylvaticus*	Knysna Warbler	Forest, Thicket	-29.4	-91.5
	Melierax canorus	Southern Pale Chanting Goshawk	Fynbos, Grassland	-14.8	-74.9
	Apus barbatus	African Black (Black) Swift	Grassland, Montane	-23.1	-63.5
	Fulica cristata	Red-knobbed Coot	Wetland	-20.4	-61.8
	Caprimulgus pectoralis	Fiery-necked Nightjar	Thicket, Urban	-19.4	-60.6
	Anas capensis	Cape Teal	Wetland	-22.9	-60.3
	Acrocephalus gracilirostris	Lesser Swamp- (Cape Reed) Warbler	Wetland	-24.3	-59.1
	Tachybaptus ruficollis	Little Grebe (Dabchick)	Wetland	-11.1	-52.5
	Microcarbo africanus	Reed (Long-tailed) Cormorant	Wetland	-11.9	-51.2
	Bubulcus ibis	Cattle Egret	Grassland, Wetland	-19.7	-50.8

(Continued)

TABLE 2 Continued

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
	Larus dominicanus	Kelp Gull	Marine	-25.0	-49.9
	Psalidoprocne pristoptera	Black Saw-wing	Forest	-27.5	-49.2
	Riparia paludicola	Brown-throated (Plain) Martin	Wetland, Fynbos	-4.7	-46.1
	Serinus canicollis	Cape (Yellow-crowned) Canary	Grassland, Fynbos, Urban	-10.8	-45.4
	Vidua macroura	Pin-tailed Whydah	Grassland, Urban	-19.7	-45.0
	Buteo buteo	Steppe (Common) Buzzard	Grassland	-17.6	-45.0
	Ardea cinerea	Grey Heron	Wetland	-13.6	-42.7
	Charadrius tricollaris	Three-banded Plover	Wetland	-15.5	-41.5
	Urocolius indicus	Red-faced Mousebird	Forest, Urban	-5.6	-39.9
	Anas erythrorhyncha	Red-billed Teal (Duck)	Wetland	-28.3	-39.3
	Ardea melanocephala	Black-headed Heron	Grassland, Wetland	-12.0	-38.3
	Cisticola textrix	Cloud (Tink-tink) Cisticola	Grassland, Fynbos	-21.2	-36.0
	Threskiornis aethiopicus	African Sacred (Sacred) Ibis	Grassland, Wetland	-3.2	-35.9
	Anhinga rufa	African Darter	Wetland	-15.4	-35
	Promerops cafer	Cape Sugarbird	Fynbos	-21.2	-34.5
	Accipiter tachiro	African Goshawk (incl. Red-chested)	Forest, Urban	-15.4	-34.3
	Elanus caeruleus	Black-shouldered (winged) Kite	Grassland, Fynbos	-13.5	-32.9
	Estrilda astrild	Common Waxbill	Grassland, Wetland	-5.5	-32.2
	Phalacrocorax lucidus	White-breasted (Great) Cormorant	Wetland, Marine	-16.0	-31.7
Yellow	*Zosterops virens*	Cape White-eye	Forest, Urban	-6.8	-29.3
	Sphenoeacus afer	Cape Grassbird	Grassland, Fynbos	-3.4	-29.0
	Corvus albicollis	White-necked Raven	Grassland, Fynbos, Montane	-10.0	-28.4
	Crithraga sulphurate	Brimstone (Bully) Canary	Forest, Fynbos, Urban	-2.8	-27.5
	Nectarinia famosa	Malachite Sunbird	Grassland, Fynbos, Urban	-4.1	-26.3
	Buteo rufofuscus	Jackal Buzzard	Fynbos, Grassland, Montane	–	-26.3
	Plectropterus gambensis	Spur-winged Goose	Grassland, Wetland	-4.6	-24.4
	Hydroprogne caspia	Caspian Tern	Wetland, Marine	–	-24.0
	Cisticola juncidis	Zitting (Fan-tailed) Cisticola	Grassland, Wetland	-1.9	-22.8
	Halcyon albiventris	Brown-hooded Kingfisher	Forest, Urban	-20.5	-22.4
	Onychognathus morio	Red-winged Starling	Fynbos, Urban, Montane	-15.1	-22.4

(Continued)

TABLE 2 Continued

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
	Cisticola tinniens	Le Vaillant's (Tinkling) Cisticola	Wetland	-14.3	-21.9
	Eupodotis vigorsii	Karoo Korhaan	Grassland	-11.1	-20.4
	Falco rupicolus	Rock Kestrel	Montane, Grassland, Fynbos, Urban	-20.6	-20.0
	Neotis denhami	Denham's (Stanley's) Bustard	Grassland, Fynbos	-15.6	-19.3
	Anas undulata	Yellow-billed Duck	Wetland	-6.3	-18.2
	Hirundo rustica	Barn (European) Swallow	Generalist	-6.7	-16.7
	Cercotrichas coryphoeus	Karoo Scrub-Robin	Fynbos, Urban	-1.4	-16.0
	Pluvialis squatarola	Grey (Black-bellied) Plover	Wetland, Marine	-16.7	-14.5
	Apus caffer	White-rumped Swift	Generalist	-14.3	-14.5
	Hirundo albigularis	White-throated Swallow	Grassland, Wetland, Fynbos	-11.9	-14.5
	Euplectes capensis	Yellow (Yellow-rumped) Bishop (Widow)	Grassland, Fynbos	-4.1	-14.5
	Ptyonoprogne fuligula	Rock Martin	Fynbos, Urban, Montane	-3.1	-14.5
	Cecropis cucullate	Greater Striped-Swallow	Grassland, Fynbos	–	-14.5
	Platalea alba	African Spoonbill	Wetland	-29.5	-14.0
	Euplectes orix	Southern Red (Red) Bishop	Grassland, Wetland	-2.8	-13.5
Green	*Laniarius ferrugineus*	Southern Boubou	Forest, Thicket, Fynbos, Urban	-4.1	-4.9
	Haliaeetus vocifer	African Fish-Eagle	Wetland	-26.2	–
	Bradypterus baboecala	Little Rush- (African Sedge) Warbler	Wetland	-25.0	–
	Cuculus solitarius	Red-chested Cuckoo	Forest, Urban	-21.7	–
	Ploceus velatus	Southern Masked-Weaver	Grassland, Wetland, Urban	-11.3	–
	Dendrocygna viduata	White-faced (Whistling-) Duck	Wetland	-10.5	–
	Saxicola torquatus	African (Common) Stonechat	Grassland	-4.1	–
	Andropadus importunes	Sombre Greenbul (Bulbul)	Forest, Thicket	-4.1	–
	Cisticola subruficapilla	Grey-backed (Red-headed) Cisticola	Fynbos	-2.7	–
	Vanellus armatus	Blacksmith Lapwing (Plover)	Grassland, Wetland	-1.6	–
	Lamprotornis bicolor	Pied (African Pied) Starling	Grassland	-1.6	–
	Bostrychia hagedash	Hadeda Ibis	Grassland, Urban	–	–
	Streptopelia semitorquata	Red-eyed Dove	Forest, Urban	–	–

(Continued)

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TABLE 2 Continued

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
	Streptopelia capicola	Cape Turtle (Ring-necked) Dove	Forest, Urban	–	–
	Lanius collaris	Common Fiscal	Grassland, Urban	–	–
	Telophorus zeylonus	Bokmakierie	Fynbos, Thicket, Grassland, Urban	–	–
	Upupa Africana	African Hoopoe	Grassland, Urban	1.4	–
	Crithagra gularis	Streaky-headed Seedeater (Canary)	Grassland, Thicket, Forest, Urban	4.5	–
	Charadrius pecuarius	Kittlitz's Plover	Wetland, Marine, Grassland	-25.0	–
	Numida meleagris	Helmeted Guineafowl	Generalist	-1.4	2.6
	Haematopus moquini	African Black Oystercatcher	Marine	-13.3	2.8
	Terpsiphone viridis	African Paradise-Flycatcher	Forest, Thicket, Urban	-8.1	5.6
	Passer diffuses	Southern Grey-headed Sparrow (split)	Grassland, Urban	-5.1	6.2
	Colius striatus	Speckled Mousebird	Forest, Thicket, Urban	–	8.3
	Apalis thoracica	Bar-throated Apalis	Forest, Thicket, Urban	-1.3	8.6
	Emberiza capensis	Cape Bunting	Montane, Grassland, Thicket, Urban	-10.0	8.7
	Crithagra albogularis	White-throated Canary	Montane, Thicket, Urban	1.5	8.7
	Hirundo dimidiate	Pearl-breasted Swallow	Grassland, Wetland, Fynbos	-16.7	9.1
	Tricholaema leucomelas	Acacia Pied (Pied) Barbet	Fynbos, Thicket, Grassland, Urban	-10.7	9.6
	Crithagra flaviventris	Yellow Canary	Grassland, Urban	1.4	9.8
Blue	*Dicrurus adsimilis*	Fork-tailed Drongo	Forest, Thicket, Urban	-2.8	10.7
	Cossypha caffra	Cape Robin-Chat	Forest, Thicket, Urban	–	10.7
	Macronyx capensis	Cape (Orange-throated) Longclaw	Grassland, Fynbos	-12.3	11.1
	Sterna hirundo	Common Tern	Marine	-20.0	11.5
	Turdus olivaceus	Olive Thrush (split)	Forest, Urban	-16.3	11.5
	Tadorna cana	South African Shelduck	Wetland	-23.5	12.6
	Columba guinea	Speckled (Rock) Pigeon	Montane, Grassland, Urban	–	12.9
	Cisticola fulvicapilla	Neddicky (Piping Cisticola)	Grassland, Fynbos	–	13.0
	Apus affinis	Little Swift	Generalist	-6.9	13.3
	Chrysococcyx klaas	Klaas's Cuckoo	Forest, Urban	-20.0	13.5
	Melaenornis silens	Fiscal Flycatcher	Thicket, Urban	–	14.2
	Motacilla capensis	Cape Wagtail	Wetland, Urban	–	14.4

(Continued)

TABLE 2 Continued

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
	Burhinus vermiculatus	Water Thick-knee (Dikkop)	Wetland	-24.0	15.4
	Bubo africanus	Spotted Eagle-Owl	Grassland, Forest, Urban	-20.4	15.4
	Vanellus coronatus	Crowned Lapwing (Plover)	Grassland	-1.4	15.8
	Grus paradisea	Blue Crane	Grassland	-1.4	16.1
	Prinia maculosa	Karoo Prinia (split)	Fynbos, Thicket, Urban	–	16.7
	Certhilauda brevirostris	Agulhas Long-billed Lark (split)	Grassland	-1.7	17.0
	Chalcomitra amethystine	Amethyst (Black) Sunbird	Forest, Urban	-19.6	18.3
	Tchagra tchagra	Southern Tchagra	Fynbos, Thicket, Forest	-8.6	20.5
	Burhinus capensis	Spotted Thick-knee (Dikkop)	Grassland, Urban, Marine	-12.7	22.4
	Cinnyris afer	Greater Double-collared Sunbird	Forest, Thicket, Fynbos, Urban	-8.5	26.0
	Cinnyris chalybeus	Southern Double-collared Sunbird	Forest, Thicket, Fynbos, Urban	-4.1	29.7
	Batis capensis	Cape Batis	Forest, Thicket	4.0	30.1
	Campethera notata	Knysna Woodpecker	Forest, Thicket	-3.1	30.9
	Milvus aegyptius	Yellow-billed Kite	Generalist	-11.1	32.6
	Egretta garzetta	Little Egret	Wetland, Marine	-15.4	36.5
	Corvus albus	Pied Crow	Generalist	-5.1	36.5
	Chlorophoneus olivaceus	Olive Bush-Shrike	Forest, Thicket	-2.5	36.5
	Numenius phaeopus	Common (Whimbrel) Whimbrel	Wetland, Marine	-10.0	38.0
	Anthus cinnamomeus	African (Grassveld, Grassland) Pipit	Grassland	1.5	39.6
	Phalacrocorax capensis	Cape Cormorant	Marine	-14.3	40.8
	Anthobaphes violacea	Orange-breasted Sunbird	Fynbos	-12.1	44.8
	Pternistis capensis	Cape Spurfowl (Francolin)	Fynbos, Grassland, Urban	1.4	52.6
	Galerida magnirostris	Large-billed Lark	Grassland	–	54.8
	Oenanthe familiaris	Familiar Chat	Montane, Urban	-6.1	57.8
	Mirafra apiata	Cape Clapper Lark (split)	Grassland, Fynbos	5.7	57.8
	Ploceus capensis	Cape Weaver	Grassland, Fynbos, Urban, Thicket	–	79.5
	Alophochen aegyptiaca	Egyptian Goose	Grassland, Wetland, Urban	-1.4	85.3
	Passer melanurus	Cape Sparrow	Thicket, Urban	–	85.3
	Corvus capensis	Cape (Black) Crow	Grassland	5.9	85.3
	Thalasseus sandvicensis	Sandwich Tern	Marine	–	98.9

(Continued)

TABLE 2 Continued

Alert	Species	Common name	Habitat	Range change from 2014–2021 (%)	Relative abundance change from 2014–2021 (median %)
	Pycnonotus capensis	Cape Bulbul	Forest, Fynbos, Urban	–	109.6
	Oenanthe pileata	Capped Wheatear	Grassland	-1.8	185.0
	Spilopelia senegalensis	Laughing (Palm) Dove	Grassland, Thicket, Urban	3.6	216.4
	Thalasseus bergii	Swift (Great Crested) Tern	Marine	–	251.3
	Dendropicos fuscescens	Cardinal Woodpecker	Forest, Thicket	3.8	306.3
Purple	*Passer domesticus*	House Sparrow	Urban	2.9	37.9
	Sturnus vulgaris	Common (European) Starling	Grassland, Urban	-1.3	74.5
	Quelea quelea	Red-billed Quelea	Grassland	14.3	102.3
Pink	*Calandrella cinerea*	Red-capped Lark	Grassland	12.7	63.7
	Coturnix coturnix	Common Quail	Grassland	13.0	44.8
	Oena capensis	Namaqua Dove	Grassland, Thicket	16.3	61.2
	Coccopygia melanotis	Swee (Black-faced) Waxbill (Swee)	Grassland, Urban	28.6	22.4
	Scleroptila afra	Grey-winged Francolin	Grassland, Fynbos	40.7	146.0
	Sylvietta rufescens	Long-billed (Cape) Crombec	Thicket	46.2	1714.1
	Columba arquatrix	African Olive-(Rameron) Pigeon	Forest, Thicket, Urban	50.0	98.0

Note the prevalence of Wetland and Marine species in the Red Alert category, Wetland and Grassland species in the Amber Alert category, Grassland, Fynbos and Wetland species in the Yellow Alert category, and Grassland and/or Urban species in the Purple and Pink Alert categories.

species were also the most prevalent in the Amber Alert category (15 species), closely followed by 11 Grassland species. Yellow Alert species were predominantly Grassland and Fynbos associated, followed by Wetland.

3.2 Stable and increasing species

77 species were categorised as either Green (30 species) or Blue (47) Alert levels. The most common habitat type among both Green and Blue Alert species was Urban, followed by Grassland; for Blue Alert species, these were closely followed by Thicket and Forest (Figure 1). Three potentially ecologically negative species were categorised as Purple Alerts, with increases in relative abundance exceeding 30%. All three Purple Alert species were associated with Urban and Grassland habitats (Table 2; Figure 1). Seven ecologically neutral or positive species were categorised as Pink Alerts, with range increases exceeding 11%. Among these, five species were Grassland associated, followed by a mix of Thicket, Fynbos, and Urban associated species (Table 2; Figure 1).

4 Discussion

4.1 Species statuses in a global context

Species categorised under Red and Amber Alerts may reasonably be considered the most vulnerable, and thus most in need of rapid intervention. The declines in observed range far exceeded our initial expectations; we anticipated range decreases to be largely insignificant, and that the more sensitive relative abundance metric would be necessary to categorise trends for most species. That six species showed declines exceeding 50% was an unexpected and sobering result. Our findings uncovered two realities: First, species ranges are undergoing rapid and drastic changes at a local level in Hessequa, and second, consistent citizen science monitoring efforts are capable of detecting these changes.

19 of the 23 species experiencing greatest declines in the Red Alert category were Wetland or Marine associated. This pattern carried over into the Amber category, where the relative abundance of Wetland species decreased by as much as 62%, as in the case of the Red-knobbed Coot (*F. cristata*). These declines are consistent

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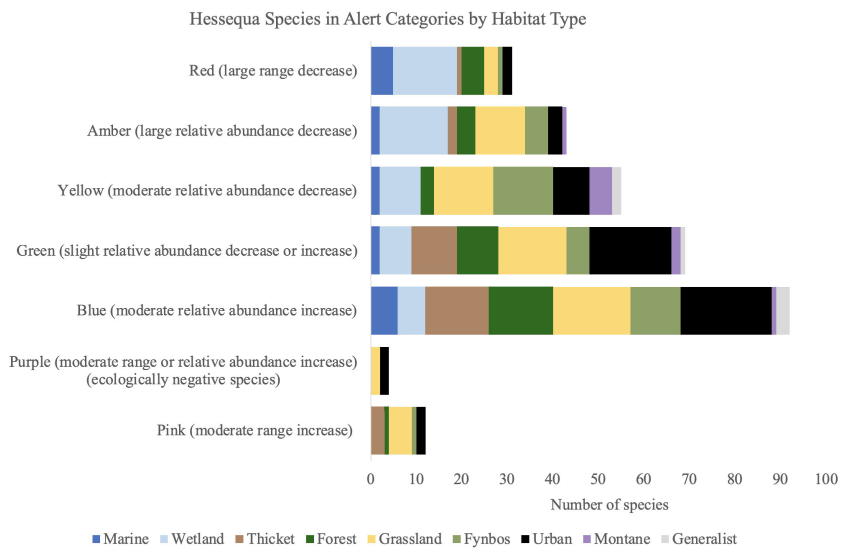

FIGURE 1
Habitat associations for 165 bird species in the Hessequa Atlasing Area, sorted into seven alert categories. Note the greatest concentration of species are those showing stable or slightly increasing populations, and populations decreasing in range and relative abundance are predominantly Wetland, Marine, and Grassland associated.

with global predictions and parallel international studies; wetlands are diminishing worldwide (Maclean et al., 2011; Prigent et al., 2012), and despite some increases in populations of wetland birds in Europe and North America (Gaget et al., 2018; Rosenberg et al., 2019; Kamp et al., 2020; Lee et al., 2022), these localised increases are not necessarily reflected elsewhere (e.g. Maclean et al., 2011; SoIB, 2020).

Species in the Yellow Alert category can be considered at-risk; these are species to watch carefully. 26 species in the Hessequa Atlasing Area fell into this category, comprising 16% of the species included in the study. Species in the Yellow category were distributed evenly across habitat types, with the strongest concentrations in Grassland, Fynbos, and Wetland habitats. These concentrations were unsurprising; a growing body of research has identified Grassland birds as among the most vulnerable groups globally (Lee et al., 2017; Correll et al., 2019; Rosenberg et al., 2019; Vaccaro et al., 2019; Marques et al., 2020; Burns et al., 2021), with distinctions between species dependent on native grassland and those able to utilise transformed grassland habitats such as agricultural fields and cattle pasture. We observed the greatest declines in Grassland species which were dependent either exclusively on natural Grasslands or on a mixture of Grassland and a second non-Urban habitat such as Fynbos or Montane. Again, this result was unsurprising; habitat specialists are more broadly threatened by habitat conversion than generalists (Clavel et al., 2011; Le Viol et al., 2012; Sweeney and Jarzyna, 2022). However, for those species able to utilise converted land, no single type of agricultural transformation appears to be conclusively "better" for avian diversity—factors supporting the greatest diversity of Grassland species vary significantly by context, rendering blanket recommendations inadequate (e.g. Batáry et al., 2006; Gil-Tena et al., 2015; Vaccaro et al., 2019; Sasaki et al., 2020). Thus, any conservation measures on behalf of local Grassland species must take local landscape into consideration.

Green and Blue Alert species comprised roughly 47% of the species included in our analysis. This is an encouraging statistic, suggesting that for nearly half of the most common species in Hessequa, populations are either stable or moderately increasing. Green and Blue categories offer insights into the factors supporting successful populations; for instance, Urban, Grassland (transformed), and Thicket associated species were more prevalent in these two categories than any other, suggesting that these habitat types may be expanding, well-managed, or alternatively are suitable as secondary habitat choices for several species. However, more targeted examination is needed to determine the underlying drivers of increasing populations, and to determine whether any of these may be linked to corresponding population declines among Red, Amber, or Yellow Alert species. For instance, some Thicket species may be increasing due to the establishment of invasive Acacia thickets (Rogers and Chown, 2013); such novel ecosystems invariably produce mixed conservation outcomes, highlighting the importance of monitoring at both the species and landscape level in parallel. Finally, Blue and Green Alert categories also included species classified as Near Threatened by BirdLife: Agulhas Long-billed Lark (*C. brevirostris*), Knysna Woodpecker (*C. notata*), and South Africa's national bird, the Blue Crane (*A. paradiseus*), all of which showed increases in relative abundance ranging from 16 to 30% in Hessequa. It is important to note, however, that regional increases do not necessarily imply species-wide increases; this concept is explored later in this paper.

Three species were categorised as both ecologically negative and showing a large increase in range or relative abundance. Note that "negative" does not necessarily denote "harmful;" introduced and alien invasive species were categorised as ecologically negative regardless of the magnitude of threat posed to local ecosystems. Two of the three species identified, House Sparrow (*P. domesticus*) and Common Starling (*S. vulgaris*), are non-native to South Africa. The third, Red-billed Quelea (*Q. quelea*), is a native species that has expanded its range southwards into the Western Cape (Oschadleus and Underhill, 2006), and is widely considered an agricultural pest, responsible for economically significant grain crop damage (Berruti, 2000; Oduntan et al., 2015).

Though introduced species are a topic of contention in ecology, the implications of expanding House Sparrow and Common Starling populations in southern Africa are little known. House Sparrows were first introduced to southern Africa in the 1900s and spread rapidly between human settlements (Msimanga, 2001). Although the species is considered invasive, current knowledge of any potentially negative impacts of House Sparrows in South Africa is limited; a study in KwaZulu-Natal showed that local populations were concentrated in heavily transformed urban environments (e.g. shopping centres and industrial areas), and thus may not compete with or threaten native species (Magudu and Downs, 2015). Like House Sparrows, Common Starlings were introduced; 18 birds were brought to Cape Town in 1897 by Cecil Rhodes, and within 50 years, were abundant across many parts of the Western Cape (Winterbottom and Liversidge, 1954). Although they are often found in dense aggregations, some evidence indicates that populations of Common Starlings in South Africa do not necessarily persist within a region once established (Ivanova and Symes, 2018); thus, like House Sparrows, they may not pose serious threat to native avian species.

As an agricultural pest species, Red-billed Quelea pose a social-ecological challenge, and we observed a range increase of 14% and an estimated increase in relative abundance of 102% in Hessequa. Although these numbers certainly seem to indicate a rapidly growing population, there are important details to note regarding the species' biology and phenology. Red-billed Queleas are nomadic and migratory across their range in response to rainfall events (Elliott, 1990; Oschadleus, 2000; Dallimer and Jones, 2002) and require a specific suite of environmental conditions to establish breeding colonies (Cheke et al., 2007). Climate patterns in the southern Western Cape are highly variable from year to year and are further complexified by the presence of microclimates (Ward et al., 2021). During our seven-year study period, Hessequa's erratic climate may have provided suitable quelea conditions over several consecutive years, with no guarantee of the conditions persisting. Alternatively, microclimates may create enough variation within Hessequa to support quelea populations year-round; this is not far-fetched, as Red-billed Quelea have been observed breeding in the Western Cape (Oschadleus, 2015). Once again, our findings showcase the value of local monitoring. Paired with climate variables and predictive models, data like those from Hessequa could inform farmers across the Red-billed Quelea's range regarding when and where populations are most likely to arrive or persist, potentially preventing large-scale crop damage.

4.2 How can an alert categories inform action?

Population change does not occur in isolation. Shifts in range and relative abundance are inextricably linked to landscape ecology, climate, and anthropogenic activity. In general, the changes we observed followed a broad trajectory, with Wetland and Marine species experiencing the greatest declines, followed by Grassland and Fynbos species with moderate declines to moderate increases, and finally Urban, (agricultural) Grassland, Forest, and Thicket species remaining stable or showing significant increases. These habitat-level observations bring opportunities to explore the nuances in observed trends: Why did some Grassland species increase and others decrease? Are decreasing species habitat or dietary specialists, and are increasing species able to utilise multiple habitat and food types? Such questions lead to a deeper understanding of the niches which species occupy within a habitat, which in turn enhances our ability to design meaningful interventions.

Perhaps the best primary application for Red and Amber (or indeed any) species lists is as a tool for awareness; through facilitated workshops, local citizens and citizen science participants can be made aware of the species they are losing, and introduced, where relevant, to the habitats they share with birds (e.g. Senabre Hidalgo et al., 2021). Workshops can also incorporate community reflection, with interdisciplinary conservation practitioners working together to guide communities in considering their relationships to the declining species: Are people aware of these birds, where they live, and how they move through the world? What, if anything, makes them important to members of the community? Are there elements of cultural heritage or tradition linked to the species? What would be sacrificed in losing the species within the region? Such questions encourage individuals to consider their citizenship in ecosystems and more-than-human communities, paving pathways towards integrative experiences of nature.

A secondary purpose for Red and Amber Alerts is as an advisory tool for conservation scientists, providing guidance for determining which species are at greatest risk, prioritising and refining management, and structuring education and outreach. For instance, Wetland bird population trends are strongly associated with effective governance, and countries with weaker conservation governance see greater population declines (Amano et al., 2017; Gaget et al., 2018). Additionally, data deficiencies in countries with poor governance may skew understandings of actual population statuses and threats (Amano et al., 2017; Lee et al., 2022). In these contexts, local projects like the SABAP2 monitoring in Hessequa are crucial; if Wetland bird populations are known to be closely linked with conservation governance, SABAP2 data can be used to not only observe population trends in relation to land change, but also to monitor the effectiveness of governance and interventions (e.g. Linz, 2020).

Yellow Alerts are arguably the most critical for conservationists to consider: which species are beginning to decline, and where are they? Identifying these species early on allows scientists to stage preventative interventions rather than attempting to halt or reverse already significant declines. For Hessequa, since the Yellow Alert list was relatively short (26 species), it may be feasible to craft individually targeted studies, perhaps incentivising postgraduate research or community-led citizen science projects that investigate the factors influencing observed declines for a particular species. As well as bolstering current knowledge surrounding the species at risk, such projects also encourage a deeper civic awareness of local conservation challenges, and offer opportunities for local communities to form unique relationships with specific target species in their region (e.g. Kobori et al., 2016). There is evidence that meaningful connections with one element of non-human nature facilitate a broader and healthier relationship with non-human nature as a whole (Evans et al., 2005; Toomey and Domroese, 2013) and may even increase species advocacy (Forrester et al., 2017). Yellow Alert species may provide an ideal starting point for local non-scientist community members to engage with the rest of the natural world.

With the rise of concepts such as Essential Biodiversity Variables and increasing understandings of the importance of species diversity in ecosystems, it is quickly apparent that monitoring data are valuable for all species and populations—rare, threatened, stable, and increasing (Pereira et al., 2013; McGeoch and Latombe, 2015; Weeks et al., 2022). In this way, Green and Blue categories can still be considered 'Alerts,' as they provide critical baseline data for species that are doing well, but can also trigger further investigation for species potentially beginning to experience significant population increases. For instance, in our study, Blue Crane relative abundance was estimated to have increased by 16% between 2014 and 2021. This species is a national icon and is listed as Vulnerable by the IUCN RedList (2022) with a declining global population trend; thus, continued regional increases over a seven-year period are an encouraging statistic. Patterns like these for Green and Blue Alert species can inform research initiatives focussed on the factors supporting population increases, potentially enhancing conservation interventions for the species in other parts of their range.

Similarly, Purple Alerts are important for understanding the local implications of a species population increase. For potentially problematic species (i.e. Red-billed Quelea), a Purple Alert deepens existing knowledge of species movements and can open opportunities to engage with the people who are most affected by them. There is also opportunity for broader ecological learning; for instance, although further research is needed to understand the implications of House Sparrow and Common Starling expansion in South Africa, it is known that both species have experienced substantial declines across their native ranges which cover much of continental Europe and Asia (Crick et al., 2002; Freeman et al., 2007). Reasons for these declines remain unclear (De Laet and Summers-Smith, 2007; Heldbjerg et al., 2016; Heldbjerg et al., 2019; Balmori, 2021), but as native populations decline, there is much to be learned from South Africa's invasive populations. Studies of genetic diversity, dispersal strategies, and post-invasion adaptations help to build an understanding of the factors and traits influencing invasion success (Berthouly-Salazar et al., 2013; Hanson et al., 2020; Stuart et al., 2022; Stuart et al., 2023).

Finally, for ecologically non-negative species, Pink Alerts can provide a clear indication of the habitat types expanding within a region, whilst improving understanding of the species diversity these habitats can support. As was the case in Hessequa, it is very possible that many species in this category will inhabit novel ecosystems. Mixed landscapes are a critical frontier in conservation, and Pink Alert species lists may be particularly valuable when paired with landscape change analysis and species lists from Red and Amber Alerts; taken together, the categories depict how different species respond to shared changes in habitat.

4.3 Citizen science as a monitoring tool

In every case, true data are preferable to modelled population estimates, and through their data collection efforts, citizen science participants make the notion of true data a real possibility. Although citizen science data are capable of meeting monitoring requirements, they may also be used in conjunction with existing management tools to improve understanding of population trends. For instance, when used in partnership with SABAP2 data, the alternative threat categories identified in BirdLife South Africa's 2018 publication, The State of South Africa's Birds (Taylor and Peacock, 2018), the IUCN Red List (2022), or the classification scheme for endemic birds proposed by Lee et al. (2017) can situate regional monitoring efforts in a broader national or international context, enhancing the applied value of both datasets.

Furthermore, the ability of these categories to serve as a tool for informing both scientific and non-scientific communities makes them a valuable asset to conservation research, especially as the need for interdisciplinary collaboration, inclusivity, and community integration becomes increasingly apparent (Tallis and Lubchenco, 2014; Gavin et al., 2015; Raymond et al., 2022). Besides the importance of the data themselves, it is also necessary to acknowledge the role of regional-scale monitoring efforts in shaping community-level conservation. As noted by Kobori et al. (2016), "*A future in which national experiments are launched to address specific environmental or biodiversity problems would certainly bode well for engaging the public in the problems of the day*." Beyond collecting critical monitoring data, participatory early warning systems (alerts) encourage local awareness of environmental challenges and offer a sense of investment and ownership in regional-scale conservation (Seng, 2012; Weise et al., 2019; Tabor and Holland, 2020). In Hessequa, a small community of bird atlasers were able to generate data of sufficient quality to detect local declines. The success here suggests that implementing similar projects elsewhere may strengthen existing knowledges of species distributions, ranges, and abundance, but may also strengthen community support for the conservation measures taken on their behalf. Our study in Hessequa demonstrates the power of placing citizen science at the forefront of applied conservation; a well-structured and community-led initiative has the potential to inform individuals, decisions, and policy.

4.4 Caveats regarding regional change and rare species

When considering changes in species range and relative abundance, it is necessary to keep sight of a global context. A regional increase might indicate an overall increase in relative abundance across a species' entire range, but it might also equate to a regional decrease in relative abundance elsewhere. In fact, this appears to be the case for the Blue Crane; this species is relatively new in the Western Cape, where recent transformations of Fynbos and Renosterveld to artificial grassland have supported the movement of Blue Cranes into the province (McCann et al., 2007; Young and Harrison, 2020). As the concentration of Blue Cranes in the Western Cape increased, populations in eastern grassland habitats experienced sharp declines, largely driven by land transformation (McCann et al., 2007), and as of 2009, roughly half of South Africa's Blue Crane population were estimated to inhabit artificial grasslands in the Western Cape (Pettifor et al., 2009). Thus, while Blue Cranes in the Hessequa region are increasing in relative abundance, populations in other provinces are declining.

Regional changes may also reflect range changes for a species as a whole. For instance, the Knysna Warbler (*B. sylvaticus*) in our study area showed a decrease in relative abundance of 91% and is primarily associated with Thicket and Forest habitats. SABAP2 data have indicated general declines in South Africa's Forest bird species (Cooper et al., 2017), but Lee et al. (2017) found that Knysna Warbler populations were moving eastward in southern Africa. These uncertainties reiterate the importance of context surrounding an alert; local declines must be vetted against range-wide trends and species biology to understand whether the observed changes are anthropogenic or stochastic in origin (Prochazka et al., 2023). For the Knysna Warbler, several factors may be at play, as birds are likely moving eastwards in response to habitat degradation in their historic range and are also threatened by low habitat connectivity within their current range (Lee et al., 2017). Untangling the truth requires monitoring at both small and large spatial scales, and a combination of current and historic data.

Because we elected to omit rare species from our study in order to focus on the core avifaunal composition of the region, it is also necessary to consider the species we may have missed in our analyses. Some of the omitted species may have narrow ranges, and their local populations dwindled below our 5% reporting rate cut-off during the study period. This possibility is cause for concern, as it may have resulted in overlooking species most in need of rapid intervention. However, of the 158 species omitted from this study, the overwhelming majority were species at the periphery of their ranges in Hessequa. Meaningful conservation interventions for these species would be better focussed in the core of their ranges. Many of the species we omitted were also vagrants or species for whom there is no suitable permanent habitat in Hessequa, though a few were cryptic species with low detection probabilities (i.e. Fynbos Buttonquail). A summary table of the omitted species is available in Appendix 1.

5 Conclusion

The value of this research is twofold: it provides valuable insight into the state of Hessequa's avian populations, and demonstrates the potential for citizen science as a monitoring tool to generate early warnings for biodiversity loss. Using systematically collected atlasing data, we were able to detect significant changes in range and relative abundance for the most commonly reported species in the Hessequa region and categorise these changes by cause for conservation concern. We found that Wetland, Marine and Grassland species in particular are experiencing severe declines and noted increases for several transformed Grassland and Urban associated species. Our alert levels can guide both conservationists and community members in understanding and engaging with the status of local species. Crucially, alert levels may be used to prioritise regional conservation interventions for particular species or habitats, and support community involvement in species conservation. These results are a testament to the value of regional-scale monitoring; in a seven-year period, citizen science participants collected a sufficient quality and quantity of data to support robust statistical analysis with meaningful conservation applications. Participatory citizen science initiatives may benefit from structuring data collection in ways similar to the Hessequa project; our research outcomes suggest that this style of monitoring benefits the scientific community (improving knowledge of species statuses), local communities (structuring conservation outreach and encouraging individuals to think about species in new ways), and ultimately, the species themselves (informing conservation intervention). Such collaborative and targeted initiatives may comprise the necessary future of an inclusive and interdisciplinary conservation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

KAD wrote the introduction, methods, results, discussion, and conclusion. LGU contributed to the methods and provided comments and feedback on the remainder of the manuscript. JAVR assisted in proofreading and revising the manuscript, and coordinated the bird atlasing efforts in Stilbaai which made this research possible. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fbirs.2024.1214800/full#supplementary-material

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