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Research article

Exploring the use of the South African nest record scheme to detect changes in phenology: a case study using four well represented species

Rebecca Muller^{1,2}, Chima Nwaogu², Barbara Helm³, B. Irene Tieleman² and Arjun Amar¹

¹FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, South Africa

²Groningen Institute for Evolutionary Life Sciences, University of Groningen, Groningen, the Netherlands

³Swiss Ornithological Institute, Sempach, Switzerland

Correspondence: Rebecca Muller (mllreb003@myuct.ac.za)

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Phenological changes are one of the most well recognised responses of organisms to climate change. The ability to detect phenological change often relies on long-term datasets, which are scarce in the Southern Hemisphere. As the adaptive capacity of species is highly variable, it is important to better understand how species in the Southern Hemisphere may respond to climate change through shifts in their annual cycles. Citizen science projects, like bird nest record schemes, offer valuable long-term data, although data heterogeneity can pose challenges, affecting their use in research. To investigate the suitability of the South African nest record scheme (SANRS) for estimating phenological shifts, we conducted a preliminary exploration of shifts in lay dates in four well-represented species. Firstly, we explore the composition of nest cards for each species, specifically the proportions of single- and multi-visit cards. Secondly, we explore the accuracy of single-visit cards for estimating lay dates compared to more accurate multi-visit cards. Lastly, we compared analytical approaches to test for possible shifts in lay dates. We found little differences for lay date estimates between single and multi-visit cards and our different models showed similar patterns of lay date shifts for all species. Three of our four species (African paradise flycatcher *Terpsiphone viridis*, cape turtle dove *Streptopelia capicola*, cape wagtail *Motacilla capensis* and laughing dove *Spilopelia senegalensis*) showed a shift toward later laying over the period 1950–1999. Although only based on a limited number of species, this consistent pattern towards later lay dates contrasts with the general trends found in the Northern Hemisphere for shifts toward earlier laying. The mechanisms driving these shifts is currently unclear, but in contrast to the Northern Hemisphere, in this region rainfall rather than temperature may have a stronger influence on avian breeding phenology. Our results highlight the potential of the South African Nest Record Scheme to detect shifts in laying dates, paving the way for more extensive studies of phenological changes, and the mechanisms involved, in the under-researched region.

Keywords: estimating lay dates, nest record scheme, phenology, South Africa



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Introduction

As climates change, detecting biological responses is increasingly important. Changes in phenology, such as the timing of breeding or flowering, are among the most profound responses to climatic shifts (Walther et al. 2002). It has also been well established that climate change impacts regions unequally, with hot-spots of rapid climate change being identified in South America, Africa and Asia (Beaumont et al. 2011, Diffenbaugh and Giorgi 2012, Chambers et al. 2017). In the Southern Hemisphere, rainfall is often considered a stronger driver of seasonal terrestrial biological responses to environmental change than day length or temperature and can vary greatly by region (Chambers et al. 2017). As species' adaptive capacities to environmental conditions vary (Dunn and Winkel 2010), assumptions about phenological shifts in Southern Hemisphere species based on Northern Hemisphere studies may be unreliable (Chambers et al. 2013, Theuerkauf et al. 2022).

Detecting phenological changes depends on long-term data sets (Parmesan and Yohe 2003, Pau et al. 2011), but their availability are often limited due to resource constraints and short study durations (Kobori et al. 2016). Geographic biases in long-term biological data reflect the longer histories of academic institutions and record-keeping in the global north (Miller-Rushing et al. 2012, Chambers et al. 2013). Consequently, more long-term data exist for north-temperate regions, where many avian phenological responses have been recorded, especially for spring migration arrivals (Forchhammer et al. 1998, Sparks and Mason 2004, Mason 2009, Jenkins and Watson 2010, Newson et al. 2016), and timing of breeding events (Crick et al. 1997, Bates et al. 2022). In the Southern Hemisphere such data are scarce, leaving much unknown about climate change impacts on phenology (Carey 2009, Chambers et al. 2013, Theuerkauf et al. 2022).

Improving data availability in the Southern Hemisphere is crucial for understanding how Southern Hemisphere species respond to climate change. Fortunately, citizen science initiatives in many countries offer valuable data for studying long-term phenological shifts. A particularly powerful citizen science scheme for studying phenology with a long tradition in ornithology are nest record card schemes. These schemes, popular in Europe and North America since the mid-20th century, involve volunteer bird enthusiasts and field biologists (BTO 2023, CLO 2023). Data from these schemes have been used successfully to estimate lay dates, a key phenological parameter for studying climate change effects (Crick et al. 1993, Møller and Hochachka 2019, Nicolau et al. 2021). In Africa, the South African nest record scheme (SANRS), active from the 1950s until ca 1999, includes data from South Africa and neighbouring countries like Zimbabwe and Zambia (Underhill et al. 1991). Despite its wealth of data, limited organisation and unclear data details have restricted its use in research. We know of only 14 publications that have made use of data from the scheme in some

way. These publications fall into three main topics: Firstly, aspects of breeding performance such as clutch size or breeding success (Hall 1959, Arkell 1979, Lepage and Lloyd 2004, McTjörve 2007, Ryan 2009, Cooper 2010, Pajmans et al. 2015); secondly, the timing or seasonality of breeding (Hall 1959, Craig 1983, Jansen and Crowe 2005, McTjörve 2007, Cooper 2010, Martin et al. 2014, Cumming et al. 2016); and finally nesting characteristics (Arkell 1979, Kuiper and Cherry 2002, Ryan 2009, Cooper 2010, Oschadlous 2022).

The data from the SANRS are yet to be used to investigate phenological shifts, and there is a need to assess their potential for phenology studies comparable to those in northern latitudes. This is particularly important given the changing climatic conditions South Africa has already experienced and will continue to experience in years to come. Since the 1960s average temperature has increase by 1.5°C, and temperature extremes have increased in both intensity and frequency (DEA 2018, USAID 2018). In addition, the rate of temperature change has varied with the highest rates of increase seen in the mid 1970s to early 1980s (USAID 2018). On the other hand, rainfall patterns in South Africa have shown a high degree of inter-annual variability, with trend for increasing intensity of rainfall events with prolonged dry spells across all hydrological zones becoming apparent (USAID 2018).

To assess whether phenological changes may be apparent for birds in the southern African region, we developed methods for extracting lay dates from the SANRS. We use an initial set of four species, whose nest cards we digitised to pilot both method development and explore phenological shifts. One important consideration for phenological analyses using SANRS data is whether we can use the less accurate single-visit cards in addition to more accurate multi-visit cards in order to maximise the available sample sizes? Multi-visit cards provide more detailed information, enabling corrections within each card to ensure accurate lay date estimates. The only other study we are aware of that has quantified the similarity estimates from single-visit cards to those from multi-visit cards was Duursma et al. (2017), who emphasised the usefulness of including single-visit cards in their analyses of data from the Australian nest record scheme.

The aim of this study is to test whether breeding phenology has shifted over time for four widespread, common bird species in South Africa, which were well-represented in the SANRS: African paradise flycatcher *Terpsiphone viridis*, cape turtle dove *Streptopelia capicola*, cape wagtail *Motacilla capensis* and laughing dove *Spilopelia senegalensis*. To do this we first conducted an assessment of the suitability of single-visit cards in addition to multi-visit cards in estimating lay dates. Specifically we looked at 1) Do single-visit cards produce similar lay date estimates to those from multi-visit cards?, 2) Which measure of lay dates from multi-visit cards in combination with single-visit cards, is the most effective for investigating possible shifts in lay dates?, and 3) Is there a shift in lay dates towards either earlier or later breeding for the four species in this pilot study?

Material and methods

Nest record cards

We selected all unique record cards from the period 1950–1999 for four common bird species (two passerines and two columbids) from the SANRS, with the most digitally available cards at the time of this study. Details of the data and the sample sizes per species are summarised in Table 1. To be included, cards had to include a location identifiable to a town level, the day, month and year of the visit had to be provided, and the type of breeding activity needed to be clear (i.e. eggs or chicks). Latitude and longitude was assigned for each card based on the town name using Google Earth and Google Maps search engines. For each species we calculated the start of egg-laying (5th percentile), the peak of egg-laying (median lay date) and length of egg-laying (number of days between the 5th and 95th percentiles) both single-visit and multi-visit cards (Duursma et al. 2017). We also calculated the proportion of multi-visit cards for each species.

Lay date calculations

Transforming dates to Julian dates can help with laying date calculations, however such conversions are still problematic when breeding events overlap the turn of the calendar year, where Julian dates change dramatically from 365 to 1 (31 December–1 January). To deal with these artefacts we created a new day 1 based on when there was the least amount of breeding activity across all species. Therefore our new day 1 was assigned to Julian Day 166 or 15 June. We distinguished two types of nest cards: 1) multi-visit cards, where two or more visits were made to the same nest during the same breeding attempt and the type of breeding activity was recorded, or 2) single-visit cards, where only one visit was made to a nest and either eggs or young were observed.

From the observations on the cards we calculate a lay date using modified formulas based on Crick et al. (2003) and Duursma et al. (2017). For every individual row or observation on both single- and multi-visit cards, the formulas were used to calculate an earliest possible and latest possible lay date. The estimated lay date was the midpoint between the

earliest and latest possible lay dates. Estimated lay dates with a window of more than ± 7 days were excluded from analyses.

Earliest for eggs:

$$\text{LayDate} = \text{obdate} - \text{inc.p} - (\text{egg.i} \times (\text{En} - 1))$$

Latest for eggs:

$$\text{LayDate} = \text{obdate} - (\text{egg.i} \times (\text{En} - 1))$$

Earliest for young:

$$\text{LayDate} = \text{obdate} - \text{inc.p} - \text{nest.p} - (\text{egg.i} \times (\text{Yn} - 1))$$

Latest for young:

$$\text{LayDate} = \text{obdate} - \text{inc.p} - (\text{egg.i} \times (\text{Yn} - 1))$$

Where obdate = date the observation was made; inc.p = incubation period; egg.i = egg laying interval; En = number of eggs; nest.p = nestling period; and Yn = number of young.

For all species, information on the incubation period, egg laying interval and nestling period was obtained from Hockey et al. (2005) and is displayed in Table 1.

Precision of lay date estimates from single- versus multi-visit cards

Prior to identifying temporal shifts in lay dates, we assessed whether it was viable to include lay date estimates from single-visit cards, given that they may be less accurate due to their lack of information, in combinations with more accurate lay date estimates from multi-visit cards. To do this, we first created a subset of multi-visit cards that included only those cards for which we could calculate a 'known' lay date (± 1 day accuracy) using all available information on the card (hereafter

Table 1. A summary of the available data for each species in this study. The table shows incubation period (Inc.P, in days), egg laying interval (Egg.I, in days) and nestling period (Nest.P, in days) for each species based on Hockey et al. (2005). We also report the number of nest record cards available from the South African Nest Record Scheme from 1950–1999, the total number of nest cards for which a Lay Date (LayDate) estimate was calculated, and the number of 'known-date' (± 1 day accuracy) estimates obtained from multi-visit cards (from those for which a Lay Date was calculated). It also shows the average Start (5th percentile, in days), Peak (50th percentile, in days) and Length (days between the 95th and 5th percentile) of the egg-laying period for the different types of cards, where day 1 = 1 January.

Species	Inc.P	Egg.I	Nest.P	No. Nest cards	No. LayDate	No. 'Known-date'	Record type	Start	Peak	Length
African paradise flycatcher	15	1	13	543	514	158	Single	290.7	323.5	81.8
							Multi-visit	292.5	315.5	80
Cape turtle dove	14.5	1	16.5	1750	1744	337	Single	230.8	293.8	211.2
							Multi-visit	219.3	295.5	190.7
Cape wagtail	14	1	15.5	1519	1516	396	Single	203	266	160
							Multi-visit	199	270	162
Laughing dove	13	1	14	2335	2233	554	Single	208.5	304.5	288.6
							Multi-visit	196.7	286.5	260.6

called 'known-date' cards). We then treated each individual observation from the 'known-date' cards, where each row corresponded to one observation, as a unique (or 'single-like') record. We calculated lay dates (using the formulas mentioned above) for each individual observation and compared them to the 'known-date' (± 1 day accuracy) of that record card. For each species, we performed 10 random samples (sampling with replacement), where each sample contained 25% of the subset data, and compared the mean lay date from each random sample to the mean 'known-date' from the entire subset of each species. Additionally, we illustrate this comparison separately for cards observing eggs and young.

Detecting shifts in estimated lay dates

We used linear and linear mixed models (LMs and LMMs) to detect temporal shifts in lay dates for each species. All statistical analyses were completed in R ver. 4.2.2 (www.r-project.org). Lay date (treated as normally distributed) was fitted as the response variable, with year fitted as a continuous fixed effect, together with location of the nest cards (latitude and longitude) to account for variation in timing of breeding in different regions.

The data included in each model were as follows:

1. Model 1 (LM): Only accurate 'known' lay dates from multi-visit cards. These cards contain the most accurate lay dates, but results in the smallest sample size.
2. Model 2 (LM): All single-visit lay dates and a single randomly selected lay date from multi-visit cards. This combination of observations treats all cards as single-visit by only selecting one lay date from a multi-visit cards.
3. Model 3 (LM): All single-visit lay dates and the average lay date from each multi-visit cards. This combination allows for a degree of within card correction provided by the multiple visits to a nest.
4. Model 4 (LMM): All single-visit lay dates and all lay dates from each multi-visit card (i.e. each observation on a multi-visit card has an associated lay date). This combination uses a mixed model approach with card number/identity set as a random term to maximise information for calculating lay dates without generating pseudo-replication.

Results

Nest record cards and timing of breeding

After the removal of cards with missing or ambiguous data, the number of cards per species ranged from 543 up to 2335 (Table 1). The proportion of multi-visit cards varied substantially among species, ranging from 40% for cape turtle dove to 80% for laughing dove (Fig. 2). The proportion of manually calculated 'known' lay dates (± 1 day accuracy) ranged from 19% for cape turtle dove to 30% for African paradise flycatcher (Table 1). Data came from across South Africa, but tended to cluster around major metropolitan areas such as Cape Town, Johannesburg and Durban for most species (Fig. 1).

Similar lay dates were calculated from single- and multi-visit cards, across all species. No significant differences were found in the start, peak, or length of egg-laying period between single- and multi-visit records across all species. However, species varied considerably in their egg-laying duration, from as short as 80 days (African paradise flycatcher) up to 270 days (laughing dove) (Table 1). Seasonality of breeding also varied between the species with cape wagtail starting egg laying earliest in the year, at the beginning of July, and African paradise flycatcher showed the latest start at the beginning of October (Table 1, Fig. 2).

Accuracy of lay date estimates from single- versus multi-visit cards

Generally we found that lay date estimates from single-visit cards were similar to those from the more accurate multi-visit cards (Supporting information). By selecting a random observation from multi-visit cards with 'known' lay dates, we were able to evaluate how these random 'single-like' lay dates compare to a highly accurate 'known' lay date for the same card. For all species except laughing dove, we found that the average of these 'single-like' lay dates, across 10 repeated samples, fell well within the 95% confidence interval of the average 'known' lay date for observations of eggs (incubation) as well as observations of young (nestlings) (Supporting information). For laughing doves, the average 'single-like' lay date fell just within the 95% confidence interval of the average 'known' for observations of eggs (incubation) and just outside the 95% confidence interval for observations of young (nestlings).

Detecting shifts in estimated lay dates

The results show that models 2, 3, and 4, which all contained information from single- and multi-visit cards, had similar trends in the effect of year, latitude and longitude on lay dates across all species (Fig. 3). Model 1, although containing the most accurate 'known-dates', had larger standard errors across all four species due to the smaller sample size (Fig. 3). We found evidence for temporal shifts in lay dates for three of the four species in this study. For an exploration of phenological trends, overall, Model 4 had the apparent highest power for detecting effects on lay dates. Based on Model 4, lay dates from 1950–1999 were found to have become later for African paradise flycatcher (0.09 days per year; 95% CI: 0.01–0.18), cape wagtail (0.45 days per year; 95% CI: 0.21–0.68) and laughing dove (0.70 days per year; 95% CI: 0.31–1.09). When we compared outcomes among the different models, temporal shifts in laying date for laughing dove were only found using Model 4, which was a mixed effects model containing card identity as a random effect (Fig. 3d, Supporting information). In addition, for cape wagtail, an association between laying date and latitude was only detected using Model 4 (Fig. 3c). Although cape turtle dove did not show evidence for a temporal shift in laying dates, there was evidence of an association between laying dates and latitude (Fig. 3b, Supporting information). African paradise flycatcher and cape wagtail showed evidence for variation

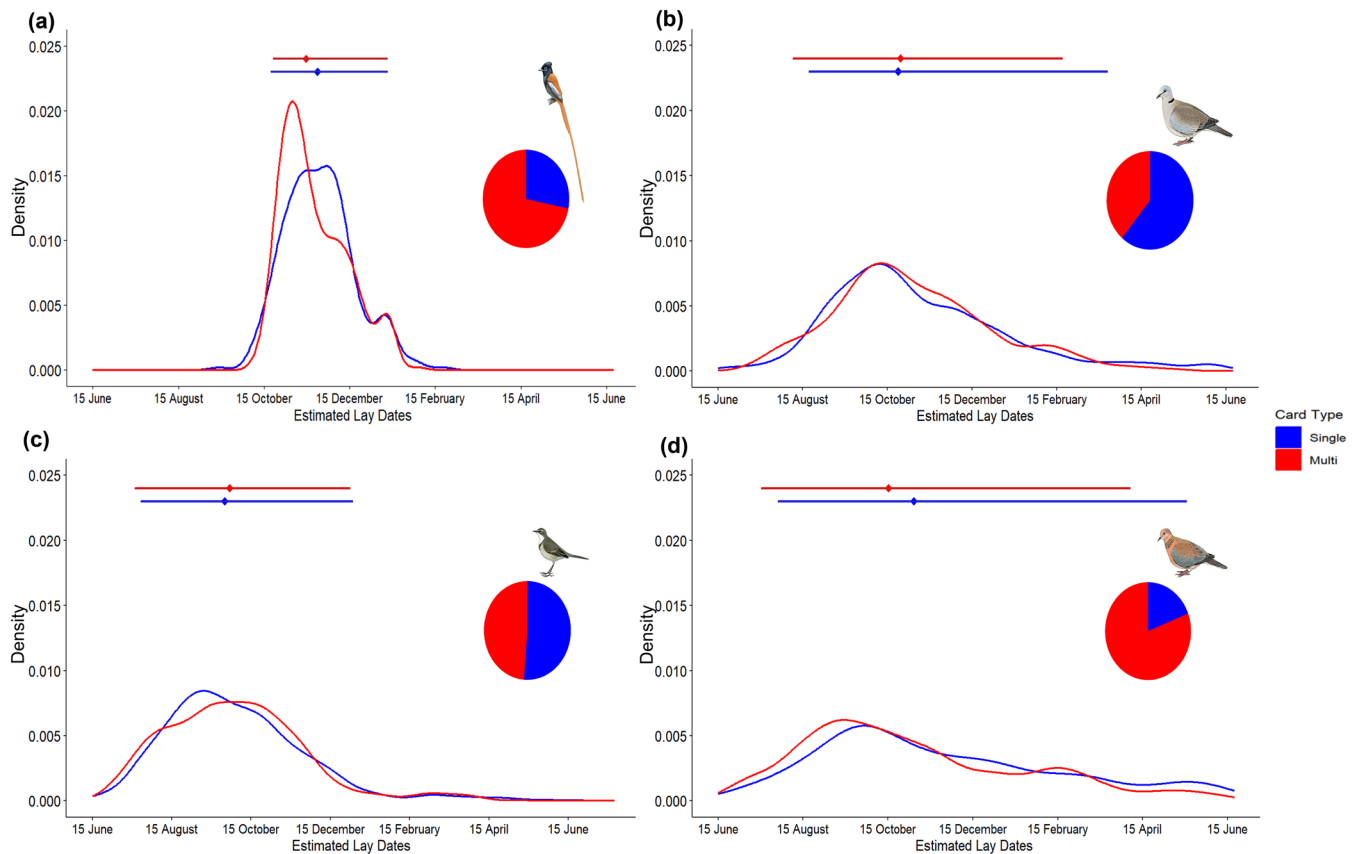


Figure 1. The overall density of estimated lay dates over a calendar year, revealing the peaks and duration of breeding for (a) African paradise flycatcher, (b) cape turtle dove, (c) cape wagtail, and (d) laughing dove. June 15 is set as day 'one' to account for breeding over the turn of calendar years. The horizontal lines above the density curves represent the length and peak (diamond) of the egg-laying period for each card type and the pie chart represents the proportion of single- (blue) and multi-visit cards (red).

in lay dates with latitude and longitude respectively, while laughing doves showed evidence for patterns in lay dates with both latitude and longitude (Fig. 3a, c, d).

Discussion

We found that data from the South African nest record card scheme (SANRS) was useful for exploring shifts in breeding phenology for species well represented by the scheme. Three of the four species we explored in this study, showed shifts toward later breeding over a 5-decade period (1950–1999). Exploring different analytical approaches, we found that including both single- and multi-visit cards was a more powerful approach to detect shifts, with the models that included only the most accurate multi-visit cards often failing to detect these shifts due to higher confidence interval of the estimated trends. Our further assessment suggested that including these single-visit cards were justified given that these single-visit cards generally produced similar lay date estimates to the multi-visit cards. We also found that using a mixed modelling approach (card fitted as a random term) was the best approach revealing shifts and minimizing the amount of pre-processing of the cards information.

The shift towards later laying in three of our studied species contrasts strongly with the trend observed in many other studies exploring shifts in avian lay dates, particularly in the Northern Hemisphere, which have found a general advancement in laying for terrestrial birds (Crick et al. 1997, Dunn and Winkel 2010, Andreasson et al. 2023). For example, Crick et al. (1997) found that from 65 UK bird species, 20 showed a significant advancement in breeding whereas only 1 species showed a significant delay. Similarly, Neate-Clegg et al. (2024) found that from 111 North American species 10 showed a significant advancement, with 1 showing a significant delay. Comparisons with shifts in phenology between the Northern and Southern Hemispheres have tended to reveal less pronounced shifts in laying dates in the Southern Hemisphere (Romano et al. 2023). Chambers et al. (2013) reviewed phenological shifts in the Southern Hemisphere, finding the majority showed no change (65%), whereas for those which did change more showed an advancement (22%) than a delay (13%), suggesting that delays in breeding may be more common in the Southern Hemisphere.

It is not entirely clear why species in South Africa may be delaying their breeding. However, it may be that cues for the timing of breeding in birds differ between regions. In the Northern Hemisphere timing of breeding is strongly

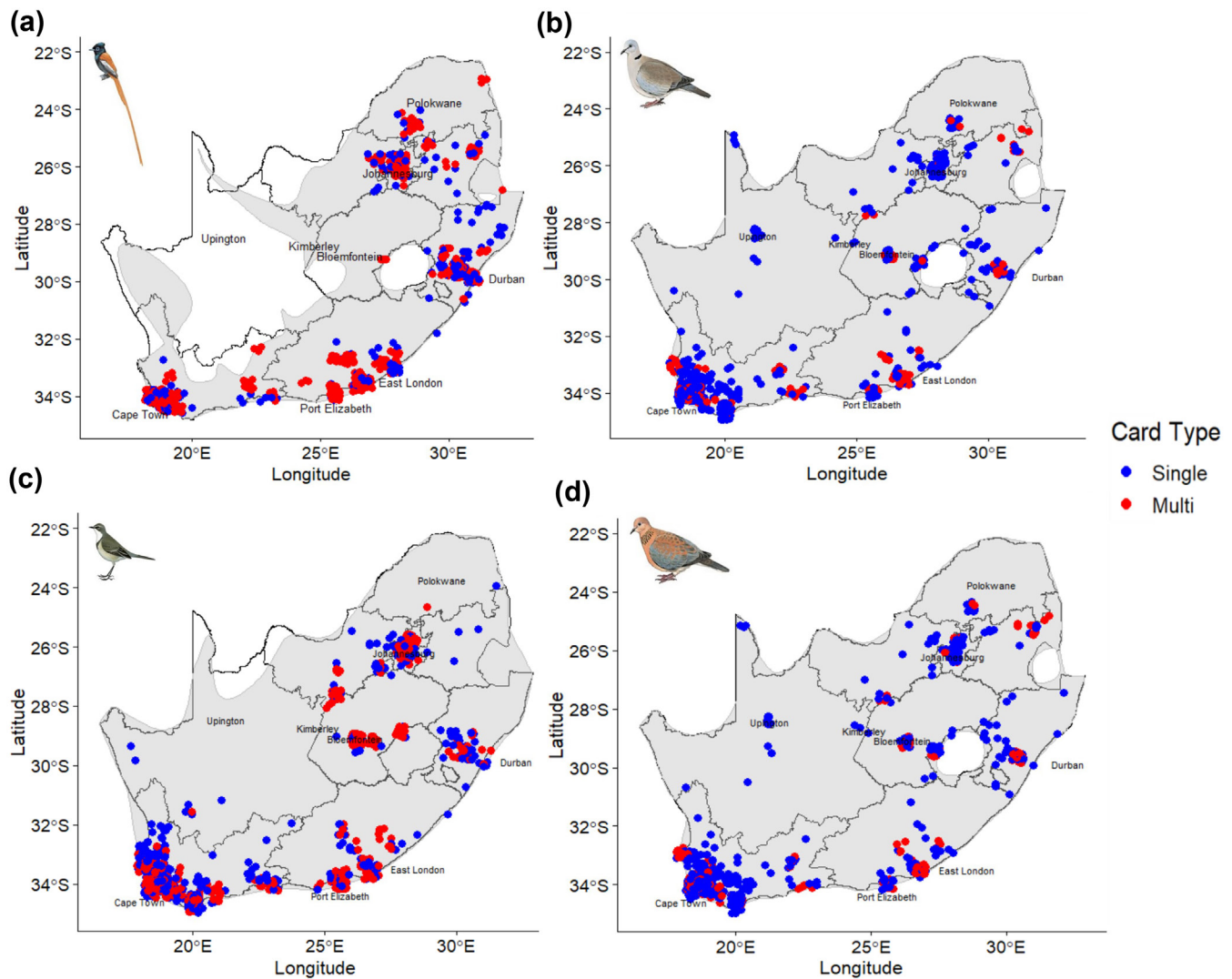


Figure 2. The distribution of single-visit (blue) and multi-visit (red) cards used to estimate lay dates for a) African paradise flycatcher, (b) cape turtle dove, (c) cape wagtail, and (d) laughing dove. In grey is the species distribution based on presence/absence data from the South Africa Bird Atlas Project 2 (SABAP 2, 2025). Major cities are labelled and provincial boundaries indicated by the black outlines.

associated with warming temperatures experienced in spring (Crick and Sparks 1999, Dunn and Winkler 1999, Dunn and Winkler 2010), whereas in the Southern Hemisphere birds may be more reliant on changing rainfall patterns than temperatures when timing their breeding (Chambers et al. 2013). Thus, changes in rainfall patterns may be the drivers behind the delayed breeding patterns we observed. However, as Chambers et al. (2013) suggest, although rainfall may be important in phenological shifts in the Southern Hemisphere, the likely direction of these responses is more challenging to predict.

Different nest record schemes have their own analytical challenges, since most have been set up independently from one another and have different natures of data collection. In the case of the SANRS, the biggest challenge we faced in using these data to explore shifts in phenology relate to high levels of single visit cards. However, previous studies

have suggested that use of these less accurate data can still be useful to explore laying dates. For example, Duursma et al. (2017) found that starts and peaks of egg-laying were similar when calculated from multi-visit and single-visit observations from the Australian nest record scheme. Slight differences in the start, peak, and length of the egg-laying periods between single- and multi-visit cards were observed in three species, with moderate differences for laughing doves (Table 1). But generally these differences were quite minimal and further support the combination of single- and multi-visit cards in our final analyses. This finding suggests that future studies using SANRS data, aimed at assessing changes in the timing of breeding in response to climate change can utilise such observational data. This will significantly increase sample sizes, rather than restricting such analyses to only using intensively tracked nests, for which accurate laying dates are available.

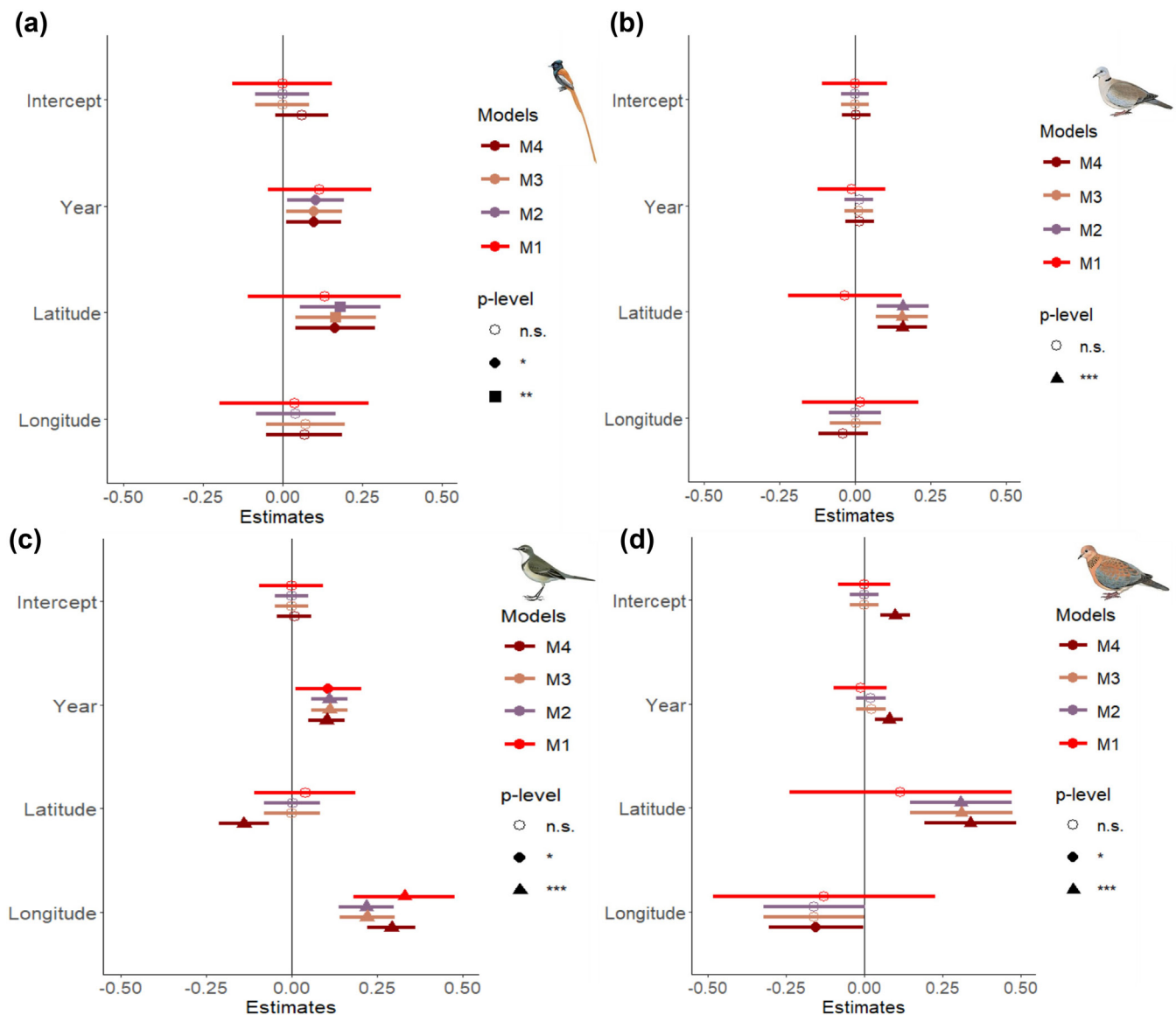


Figure 3. The results of the linear models (M1–M3) and linear mixed model (M4 – with card as random term) using different data combinations exploring association with lay date (during the period 1950–1999) for (a) African paradise flycatcher, (b) cape turtle dove, (c) cape wagtail, and (d) laughing dove. For ease of comparison, the variables were scaled and centered around zero. The error bars illustrate the confidence intervals of each estimate.

Lay dates derived from single-visit cards closely matched those from multi-visit cards, supporting the use of all available cards in analyses of breeding phenology shifts. These findings closely matched those for a similar analysis using nest record cards and other breeding records for birds in Australia (Duursma et al. 2017). This finding is particularly relevant for future SANRS studies, as single-visit cards are generally more common than multi-visit cards for most species (unpubl.). While the SANRS composition may impose some analytical constraints compared to larger Northern Hemisphere schemes, which likely have higher proportions of multi-visit cards, the difference may not be substantial. For example, Browne et al. (2005) found that 53% of turtle dove

records in Britain (1941–2000) were single-visit, comparable to several species in this study.

Across our four study species, the proportion of single- to multi-visit cards varied widely. For example, only 20% of all cards for laughing dove were single-visit whereas 60% of cape turtle dove cards were single-visit. It is unclear why such discrepancies exist between species, especially given the similarity in the breeding biology of these to species. Encouragingly, lay dates were estimated for 97.6% of all nest cards (both single- and multi-visit) and were found to be comparable between the two visit types (Supporting information). The high proportion of cards (97.6%) for which a lay date could be estimated reflects the diligent data collection by the

SANRS participants, despite the scheme holding fewer cards (~ 75 000 cards for South Africa, Underhill et al. 1991) than others, such as the British (~ 2 million cards) and Australian (~ 100 000 cards) schemes (Duursma et al. 2017, BTO 2023). Using multi-visit cards, we identified the exact lay dates (± 1 day accuracy) for between 19 and 31% of cards across the species. This level of precision is rarely reported; for instance, a study on house finch records from the larger North American scheme achieved exact lay dates for only 7.4% of cards (Watts et al. 2019). Lower card volume or fewer publications do not necessarily reflect lower data quality. Digitizing older citizen science databases is crucial for enabling studies on phenological trends and for comparing past and present data, especially for overlooked but valuable datasets with broad temporal and spatial coverage.

Our pilot phenological analyses showed that different models (varying combinations of single- and multi-visit lay dates and various analytical approaches) produced largely similar results, increasing confidence in the temporal patterns detected. Model 4 (the mixed-model approach) performed best and was the most efficient approach, showing greater sensitivity to lay date shifts during the study period while minimizing manual data processing (no reliance on manually calculated 'known dates') and maximizing sample size. We recommend using this approach (Model 4) as the primary approach for analysing phenological trends using SANRS data. Model 1, which relies on manually calculated 'known dates,' may be useful for species with highly detailed records but is less practical for multi-species analyses due to its labour-intensive processing. Additionally, using this approach produced wide confidence intervals in the slope, meaning that the significant shift in phenology for some species may be missed. The ability to detect both shifts and the absence of shifts in lay dates across species using the SANRS database is promising. As noted by previous studies (Miller-Rushing et al. 2012, Chambers et al. 2013, Kobori et al. 2016, Duursma et al. 2017), long-term phenological databases are scarce in the Southern Hemisphere and the SANRS data, therefore, represents important data for addressing these knowledge gaps. As far as we know it represents the only such database in South Africa for investigating long term trends in phenology. There are few nest record schemes in the Southern Hemisphere (Chambers et al. 2013), and thus those that do exist represent a disproportionately important data source. The tools described in this study, therefore, provide a means for optimising their use to better understand phenological shifts, through maximising the use of relatively sparse datasets.

Based on our analyses, we observed a trend for later laying between 1950–1999 for African paradise flycatcher (5 days later over 5 decades), cape wagtail (22 days later over 5 decades) and laughing dove (35 days over 5 decades) (Supporting information). The condensed breeding periods of African paradise flycatcher and cape wagtail likely made these shifts easier to detect. Although laughing doves have a prolonged breeding period, their large sample size may have facilitated detection of shifts. Cape turtle doves showed no

evidence of a shift in lay dates over the same period, likely due to their almost year-round breeding, which makes detecting shifts more challenging. Duursma et al. (2017) found that Australian species have more extensive egg-laying periods compared to highly synchronous, springtime breeding in northern temperate species. This underscores the importance of studying phenological patterns and responses to climate change within the African and broader global south context.

This study is the first to utilise data from the SANRS to assess its suitability for exploring shifts in phenology across multiple species during the latter half of the 20th century. Encouragingly, our findings highlight the utility of this citizen science database for analysing breeding phenology over broad spatial and temporal scales in a region where such data are largely absent (Chambers et al. 2013). However, the data collection of the SANRS largely stopped by the turn of the century. Climate change has accelerated over the last 2 decades, and is likely to continue to do so over the next two decades, thus, to fully understand the impacts of climate change on breeding phenology, it is important to have a continuous collection avian breeding data. Towards this goal, we recommend prioritising the establishment of a new platform for submission of nesting records. This would enable further research into both historical and contemporary phenological trends and support predictions of future shifts under various climate scenarios. Modern data could also be collected from alternative sources such as ringing schemes like the South African bird ringing unit (SAFRING), where the presence or absence of brood patches could allow for timing of breeding to be estimated (Irons et al. 2023). Additionally, integrating a dedicated framework/feature within existing platforms like eBird may provide an accessible and scalable way to collect large volumes of data from a broad user base. Our ability to successfully estimate lay dates and detect temporal and spatial shifts in egg laying demonstrates the SANRS's value in addressing knowledge gaps on phenological shifts in southern Africa. It also underscores the importance of further investigations into other long-term datasets and their potential applications in Southern Hemisphere systems.

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Author contributions

Rebecca Muller: Conceptualization (equal); Data curation (lead); Formal analysis (lead); Funding acquisition (equal); Investigation (equal); Methodology (equal); Writing – original draft (lead); Writing – review and editing (lead). **Chima**

Nwaogu: Conceptualization (equal); Funding acquisition (supporting); Supervision (supporting); Writing – review and editing (supporting). **Barbara Helm:** Conceptualization (supporting); Investigation (supporting); Supervision (supporting); Writing – review and editing (supporting); **B. Irene Tieleman:** Conceptualization (equal); Data curation (supporting); Formal analysis (supporting); Investigation (supporting); Methodology (supporting); Supervision (equal); Writing – original draft (supporting); Writing – review and editing (equal). **Arjun Amar:** Conceptualization (equal); Data curation (supporting); Formal analysis (equal); Funding acquisition (equal); Investigation (equal); Methodology (equal); Supervision (lead); Writing – original draft (supporting); Writing – review and editing (equal).

Transparent peer review

The peer review history for this article is available at <https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jav.03376>.

Data availability statement

Data are available from the Dryad Digital Repository: <https://doi.org/10.5061/dryad.0000000bz> (Muller et al. 2025).

Supporting information

The Supporting information associated with this article is available with the online version.

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