

## **Predicting the distribution of the Vulnerable Yellow-breasted Pipit (*Anthus chloris*) using Species Distribution Modelling**

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**Abstract**

The Yellow-breasted Pipit (*Anthus chloris*) is endemic to the eastern escarpment of South Africa, marginally entering eastern Lesotho. This species is classified as globally Vulnerable due to a perceived decreasing population size and loss of habitat. We employed Species Distribution Modelling to investigate the predicted range of this species to determine whether additional purportedly suitable habitat exists where this species may be found, and to assess the degree to which habitat loss has affected this species. We used a database of 250 independently obtained and verified sightings to predict the summer breeding distribution of this species and compare our verified sightings and predicted range to the sightings currently in the Second Southern African Bird Atlas Project (SABAP2) database and the latest regional conservation assessment. Our models closely approximate the current distribution of the Yellow-breasted Pipit, and suggest that most of the purportedly suitable habitat is occupied, at least at the macro-scale. Our models further suggest that the Eastern Cape Province does not hold much suitable habitat for this species, and that the purported range contraction in this region may have been overestimated.

**Key words:** *Anthus chloris*; Yellow-breasted Pipit; Breeding range; Range contraction

**Suggested running head:** Modelling Yellow-breasted Pipit distribution

## Introduction

Species Distribution Models (SDM) are becoming increasingly prevalent in ecological and biogeographical studies as a means, *inter alia*, to understand the drivers of species' distributions, predict the distributions of secretive and/or little-known species, and provide improved data for conservation assessments (Elith and Leathwick 2009; Barve *et al.* 2011; Cassini 2011; Keith *et al.* 2014; Syfert *et al.* 2014; Collins and du Toit 2016). Species Distribution Models extract predictor variable values at georeferenced occurrence locations, compare these values to sites where the species of interest has not been recorded, and based on these comparisons predict regions where these suitable variables (and thus the species) are most likely to occur (Elith and Leathwick 2009; Barve *et al.* 2011). Three basic datasets are used by SDMs to identify areas matching a species' environmental requirements, *viz.* mainly abiotic factors such as climate and topography; predominantly biotic factors such as food resources, competitors and predators; and the geographical regions that have potentially been utilised by a species over a fixed period of time, taking into account any potential barriers to dispersal (Barve *et al.* 2011). Because the biotic factors that may potentially affect a species' distribution are often too complex to include in predictive modelling, these are usually excluded (Soberón 2010; Barve *et al.* 2011).

The Yellow-breasted Pipit (*Anthus chloris*) is a southern African endemic passerine which occurs along the eastern escarpment of South Africa from Dullstroom in the north to Cathcart in the south (Clancey 1997; Barnes 2000; Voelker 2005, Peacock 2006; Little 2015; BirdLife International 2016). The majority of this species' range falls within South Africa, with marginal populations occurring in eastern Lesotho (Osborne and Tigar 1990; Clancey 1997; Voelker 2005, Peacock 2006; Little 2015; BirdLife International 2016). Small, apparently isolated populations persist in the north-eastern Eastern Cape and the eastern Free State Provinces of South Africa, with recent evidence that this species' distribution has contracted in the Eastern Cape Province (Little 2015). It has further been

suggested that this species' overall range has contracted in the past two decades, raising concerns about its population size and status (Little 2015).

The Yellow-breasted Pipit is a summer breeder, with most breeding recorded between November and February (Dean 1971; Tarboton *et al.* 1987; Clancey 1997; Muchai 2002; Little *et al.* 2015). The species breeds in lush sub-montane grasslands at altitudes above 1,400 m a.s.l., and usually at elevations of 2000–2300 m a.s.l., where they prefer grasslands that are 150–300 mm in height (Clancey 1997; Tarboton 2001; Little 2015). They are highly sensitive to burning frequency and timing as well as grazing intensity, preferring grasslands that are burnt every 2–3 years and moderately grazed (Jansen *et al.* 1999; Muchai 2002; Little 2011, 2015; Little *et al.* 2013, 2015). Although being restricted to the eastern escarpment during the breeding season, some individuals descend to lower elevations on either side of the escarpment during the non-breeding season (Clancey 1990, 1997; Peacock 2006), but due to their cryptic colouration and the consequent difficulty in identifying this species during the non-breeding season (Keith *et al.* 1992; Voelker 2005; Peacock 2006), the extent of their non-breeding range remains largely unknown.

Yellow-breasted Pipits are currently listed as globally and regionally Vulnerable owing to a projected continued reduction in the population size, a continued reduction in the species' extent of occurrence and the highly-fragmented nature of the population (Little 2015). The main factors driving this decline are believed to be habitat loss and fragmentation, mainly attributable to crop agriculture, incompatible grazing and fire regimens, and an increasing number of open-cast coal mines (Allan *et al.* 1997; Barnes 2000; Little 2011, 2015; BirdLife International 2016). This range contraction is believed to signify a concomitant overall decrease in this species' population size (Little 2015; BirdLife International 2016). In this study, we aimed to assess the potential distribution of this threatened species and to assess the potential impacts of current land use practices on this distribution.

## Methods

A total of 250 verified sighting records were sourced from specialist bird guides, databases of threatened bird species curated by provincial conservation authorities and our own field work. We did not include sightings by citizen scientists as these data are usually not accompanied by additional material such as photographs or call recordings that can be used for species verification. We restricted our database to observations made between the austral spring and autumn (August–April) because: a) successful breeding is essential to the continued existence of any species and thus we feel that it is biologically appropriate to restrict our study to this crucial period; b) Yellow-breasted Pipits obtain a conspicuous and distinctive bright yellow plumage when breeding, thus rendering them unmistakable, whereas; c) they moult into a drab grey-brown winter plumage following the breeding season which renders individuals less conspicuous (Keith *et al.* 1992; Voelker 2005; Peacock 2006) and also harder for observers not acutely familiar with this species to distinguish from sympatric pipit species. Because of this nondescript winter plumage, only a handful of verified distribution records exist for the non-breeding season and these are too few to meaningfully model. Although our database is likely to be biased towards breeding birds due to their distinctive plumage rendering them more visible and identifiable, individuals are expected to attain their breeding plumage by the first breeding season, even if they do not actively partake in breeding during their first season, and thus any bias thus induced is believed to be negligible.

We ran an initial analysis using all 250 sightings and all 19 BioClim variables as well as altitude downloaded from the WorldClim database (Hijmans *et al.* 2005, available online at <http://www.worldclim.org>) and vegetation (Mucina and Rutherford 2006), all at 30 arc-second spatial resolution (see Online Supplementary Material S1). In order to improve the predictive powers of our model we selected eight bioclimatic variables from the WorldClim database, with emphasis placed on variables pertaining to the austral summer breeding season. We also included vegetation type (Mucina and Rutherford 2006, n = 111 categories) as a predictor variable, with this latter

dataset being converted to the same spatial extent and grid size as the bioclimatic data using the Conversion tool in ArcGIS 10.4 (ESRI 2011). All data were projected to Albers Equal Area conical projection for Africa (WGS 84) prior to incorporation into the models. Predictor variables were tested for correlation in ENMTools 1.3. (Warren *et al.* 2010; Warren and Seifert 2011), and initially autocorrelated variables with ( $R \geq |0.9|$ ) were removed from the analyses (Online Supplementary Material S2) as they contain information that is already present in the other layers. Subsequently, variables that had a correlation of ( $R \geq |0.7|$ ) were removed from the analyses and a simplified vegetation layer (Acocks 1988) was employed to further improve the predictive powers of our model. This resulted in Mean temperature of the warmest quarter, Precipitation seasonality (coefficient of variation), Precipitation of the warmest quarter and Acocks' (1988) vegetation types ( $n = 19$  categories) being included in the final model.

As we specifically wanted to predict the summer breeding distribution of Yellow-breasted Pipits, we delimited a rectangle that encompassed the full extent of this species' known summer distribution, ensuring that it was at least 100 km from the nearest recorded locality at any given point. We believe that this geographic extent is reasonable for approximating the assumption of background selection as it does not include large areas of unsuitable and/or unavailable habitat (Anderson and Raza 2010; Radosavljevic and Anderson 2014). Furthermore, although the summer distribution of this species appears to be well-known, we wanted to assess whether there were any nearby regions that appeared climatically suitable for this species, and where additional populations may potentially be found.

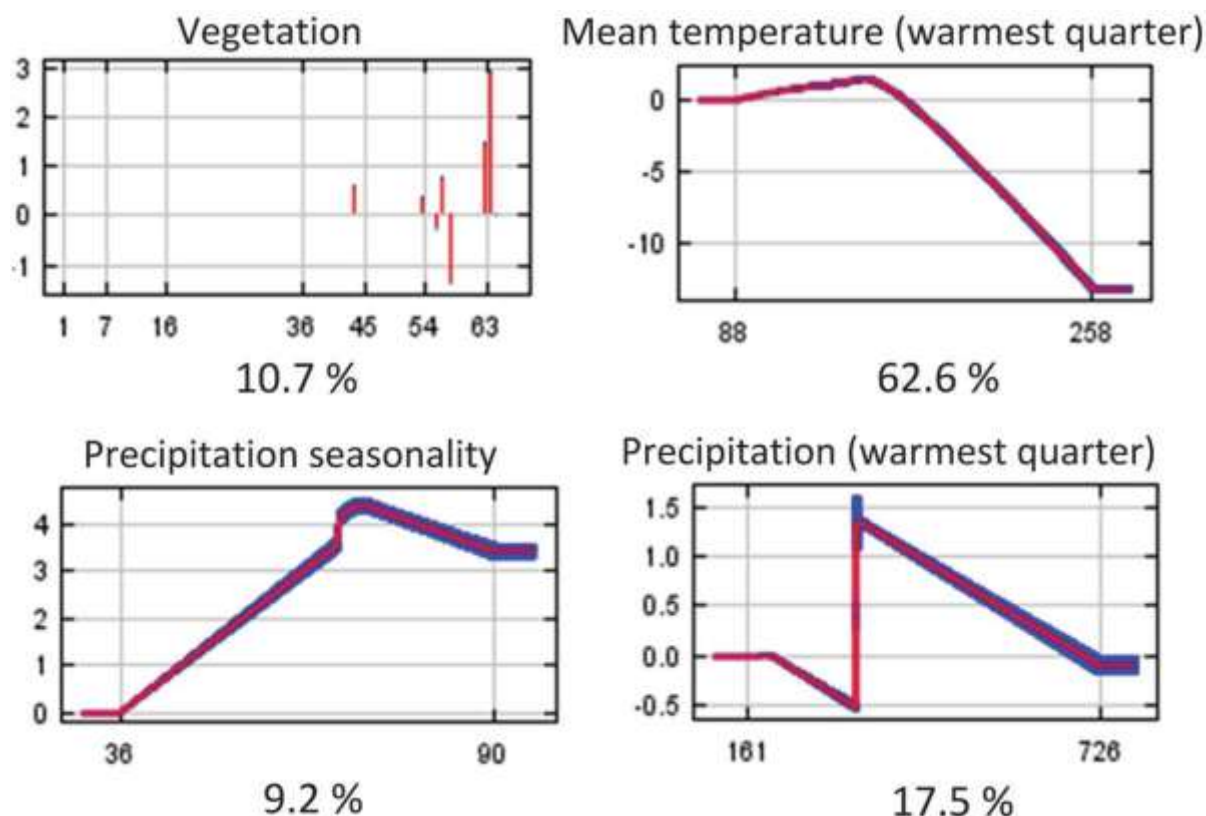
SDM analyses were executed in MaxEnt version 3.3.3k (Phillips *et al.* 2004, 2006; Phillips and Dudík 2008) with default parameters (Online Supplementary material S3), a logistic output format, 100-fold cross-validation to estimate errors around fitted functions and a maximum of 500 iterations. We enforced a Minimum Training Threshold, which represents the least suitable environmental

conditions for which a locality was available in the calibration dataset (Radosavljevic and Anderson 2014). MaxEnt uses species presence data and a set of background absence points (points randomly selected from the geographical extent of the model and assumed to represent sites where the species is absent) to predict the potential distribution of the species under investigation (Merow *et al.* 2013). MaxEnt is known to perform well with small sample sizes, as well as when using small predictor variable datasets (Jackson and Robertson 2010; Bean *et al.* 2012; Platts *et al.* 2014). We used an initial regularization multiplier of unity to prevent over-fitting of the data (Elith *et al.* 2011; Jones *et al.* 2012; Radosavljevic and Anderson 2014), and progressively increased this value to investigate the effects of the regularization factor on model performance. Model performance was determined by examining the Area Under the Curve (AUC) value and visually inspecting the resultant predicted distributions.

## Results

Our dataset included 250 independently sourced and verified sightings made between January 2000 and January 2016, which thus represent the current distribution of this species. The final model showed a high discrimination potential, with an AUC value of 0.97, where an AUC value  $\geq 0.75$  is generally accepted as indicating a potentially informative model (Fielding and Bell 1997; Phillips and Dudík 2008). Increasing the regularization factor initially resulted in a reduction in overfitting of the data, but at regularisation values of three and four the models started to lose some of their discriminatory ability, albeit only marginally (Online Supplementary Material S4–S9). The model with a regularization factor of two was selected as the best model as it provided the best discriminatory ability while not overfitting the data. Mean temperature of the warmest quarter was the most informative predictor variable when viewed in isolation, contributing 62.6 % to the model prediction (Figure 1). Mean temperature of the warmest quarter also had the most information not contained in any of the other variables.

**Figure 1.** Partial dependence plots showing the mean (dark grey) and standard deviation (light grey) marginal response curves of the Yellow-breasted Pipit (*Anthus chloris*) to each of the four environmental variables used to model its distribution. A regularisation factor of two was used to prevent over-fitting of the model. Bars in the vegetation partial dependence plot represent each vegetation type, with absent vegetation types having been regularised out of the model. The y-axis indicates logistic output, and the variable importance is indicated below each graph.

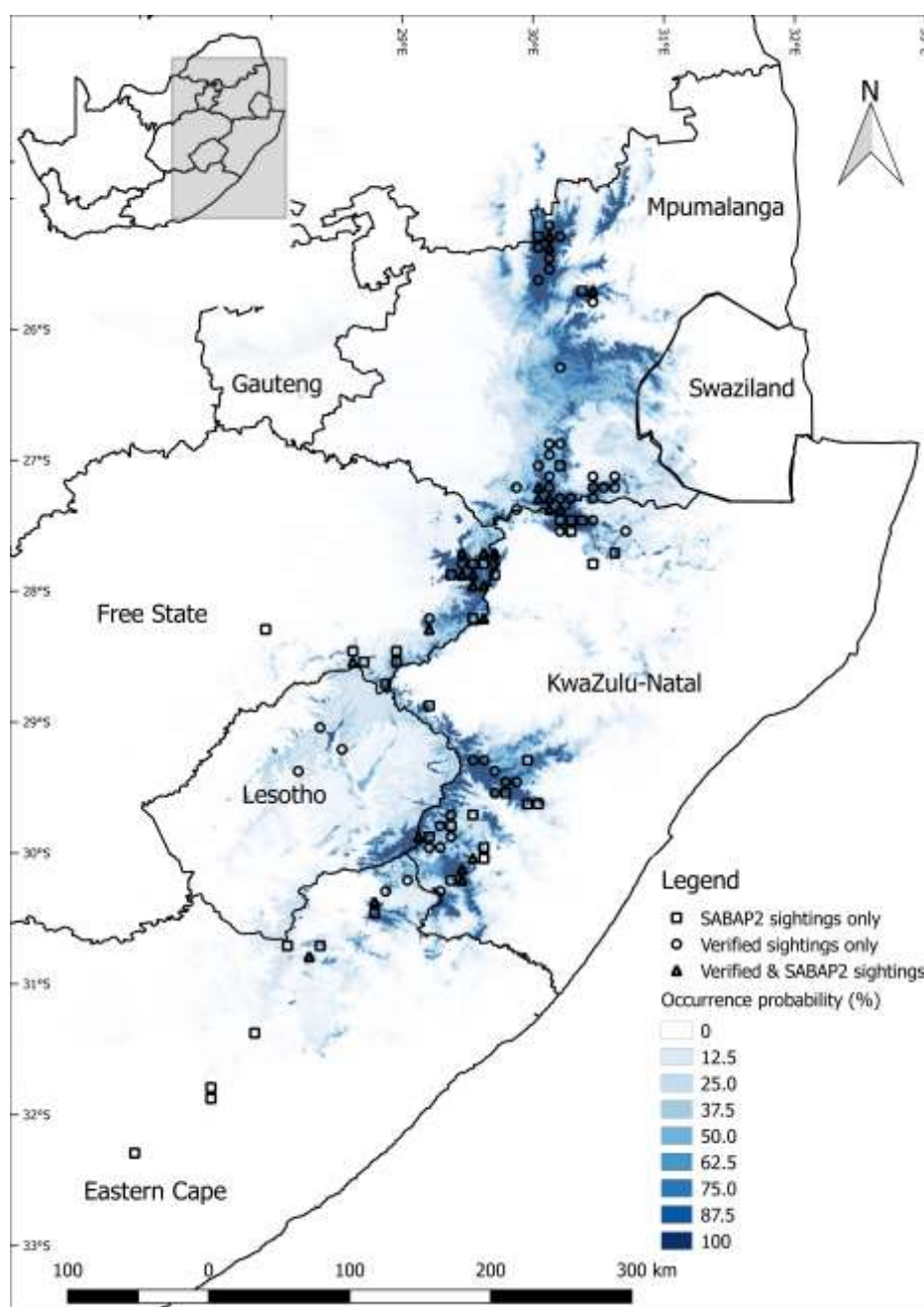


The relative probability of occurrence of Yellow-breasted Pipits as inferred from the best-performing model closely mirrored this species' actual distribution when considering both our sightings and the verified SABAP2 sightings (Figure 2). The modelled distribution reflected the SABAP2 data in indicating core populations around the Steenkampsberg (Dullstroom), Wakkerstroom, Memel and the southern Drakensberg foothills, but differed in also indicating purportedly suitable habitat in the Lydenburg-Ohrigstad region in Mpumalanga Province. The model further indicated that all of the purportedly suitable habitat is restricted to a fairly narrow belt along the Eastern Escarpment of



South Africa, and failed to indicate any significant areas of purportedly suitable habitat in the Eastern Cape Province.

**Figure 2.** Relative probability of occurrence of the Yellow-breasted Pipit (*Anthus chloris*) in southern Africa as inferred in MaxEnt using 250 verified observations and four environmental variables. Data from the Second Southern African Bird Atlas Project (SABAP2) includes only observations made between the austral spring and autumn (August–April), and were not used to predict the distribution of the species. Inset: map of southern Africa, indicating the magnified region.



## Discussion

Our model is closely congruent with the summer distribution of Yellow-breasted Pipits as reflected in the SABAP2 database and the most recent regional Red List Assessment (Little 2015). However, our model predicted some additional purportedly highly suitable habitat in the Lydenburg-Ohrigstad region in Mpumalanga Province. Despite there not being any known barriers to dispersal between this site and the nearby Steenkampsberg (Dullstroom) population, as yet there are no verified records of this species at the former site (Tarboton *et al.* 1987; Clancey 1997; Barnes 2000; Voelker 2005; Peacock 2006; Little 2015). This sites' close proximity to scarp forests, where potential predators such as *Accipiter* raptors are more common, may potentially explain the apparent absence of Yellow-breasted Pipits from this area, especially as the extended display flight of male Yellow-breasted Pipits, together with their bright colouration, may make this species particularly vulnerable to predation by Rufous-breasted Sparrowhawks (*Accipiter rufiventris*) and other avian predators (D.W. Pietersen, R. Jansen and I.T. Little, *pers. obs.*). In addition, certain regions, particularly in the foothills of the central Drakensberg mountain range, are predicted to represent suitable habitat for this species but largely lack sightings. This may reflect observer bias, perhaps due to limited access to these regions, or may suggest that additional factor(s) that we did not incorporate in our models also play a role in shaping this species' distribution.

Our data suggest that this species is occupying most of the predicted suitable areas, however at the finer scale land management practices such as grazing intensity and the seasonality and frequency of fires are known to be negatively impacting this species (Jansen *et al.* 1999; Muchai 2002; Little 2011, 2015; Little *et al.* 2013, 2015), and Barnes (2000) estimated that this species uses <10% of the available habitat. Our data also support previous assertions that this species is restricted to a relatively narrow belt along the eastern escarpment during its breeding season, in an area that is prone to habitat transformation due to commercial agriculture, afforestation and an increasing prevalence of open-cast coal mines (Allan *et al.* 1997; Barnes 2000; Little 2011, 2015; BirdLife

International 2016). As such, a concerted effort should be made to protect the remaining suitable habitat in this region, acquire additional suitable habitat, and ensure the persistence of dispersal corridors between the remaining stronghold populations. As most of this species' breeding range falls outside of protected areas, private landowners should be engaged with the view of employing compatible land management practices that will ensure the co-existence of farmers and Yellow-breasted Pipits. Such practices include burning grasslands only every 2–3 years and only burning in winter, thus ensuring that the grass sward has sufficient time to recover and provide sufficient protection to nesting Yellow-breasted Pipits (Little 2011, 2015; Little *et al.* 2013). Grazing should also be conservative and stocking rates should not exceed 5 ha/LAU (Little 2011, 2015).

Our results suggest that the purported range contractions in the Eastern Cape Province (Little 2015) may be an artefact of the data rather than a genuine contraction in the summer breeding distribution of this species. The data used to infer this range contraction were collected by citizen scientists during two successive atlassing periods (SABAP1: 1987–1991, SABAP2: 2007–present) and as far as we can establish, no effort was made to account for differences in atlassing intensity or observer ability for either of these periods, nor was the season(s) in which the respective records were made taken into account. Another potential explanation is that the aforementioned records from the Eastern Cape Province may indicate individuals reacting to extreme climatic conditions such as drought, as local movements have been observed in other portions of this species' range in reaction to severe droughts (D.W. Pietersen, *pers. obs.*).

Sightings of this species, especially in the Eastern Cape, Lesotho and central Free State, in areas not having a high predicted occurrence potential may be attributable to non-breeding birds either seeking breeding territories or occupying sub-optimal habitats, birds still on passage to their breeding grounds, or misidentifications by citizen scientists. Alternatively, these sightings could also suggest that additional factor(s) which we did not include in our models may also influence the

distribution of this species. Such factors may include aberrant movements in response to droughts, as have been recorded in other portions of this species' range (D.W. Pietersen, *pers. obs.*). Further field studies are required to better understand the biology of this species, which in turn would result in further refinement of the species distribution model. Furthermore, as individual survival is also crucial to the survival of the species, it would be informative to determine the winter range of this species through a combination of verified field sightings and Species Distribution Modelling. This would allow conservationists to assess where the greatest threats to this species' continued survival are, thus facilitating the compilation of a holistic Species Action Plan.

The finding that Mean temperature of the warmest quarter had the greatest predictive power of the summer breeding distribution of Yellow-breasted Pipits is surprising, as we expected vegetation type to be the most important predictor. However, this result is congruent with the fact that both temperature and rainfall would influence vegetation type, and thus the predictive power of vegetation structure is likely incorporated to a large extent in the other environmental variables that we included in our study. The comparatively poor predictive ability of vegetation type may also be as a result of the relatively coarse vegetation types that we included in our final model.

We obtained a number of verified sightings that fell within pentads in which this species has not yet been recorded during SABAP2, suggesting that this species' range may be larger than currently predicted if only SABAP2 data are considered, albeit marginally. Of particular interest are the three verified records from northern Lesotho. Osborne and Tigar (1990) are of the opinion that this species was previously more widespread in Lesotho, but that overgrazing and excessive burning in unprotected areas has limited its distribution to the Sehlabathebe National Park. Although Little (2015) mentioned the presence of a potential population here, it was not plotted in that publication. Despite our data not predicting a high probability of this species occurring in northern Lesotho during the summer breeding season, the aforementioned records may suggest that improvements in

grazing and burning practices in this region may have resulted in this area again becoming suitable for Yellow-breasted Pipits (Little 2015), although it remains to be seen whether these sightings represent transient individuals or whether this is the start of a population (re-)establishment.

### **Acknowledgements**

The DST/NRF Centre of Excellence at the Percy FitzPatrick Institute of African Ornithology, The Rufford Small Grants Fund (Grant no. 16316-1), Tshwane University of Technology, The Endangered Wildlife Trust and the University of Pretoria are thanked for financial and in-kind support. David Allan, Robin Colyn, Greg Davies, John Davies, Bradley Gibbons, Stuart MacLean, Duncan McKenzie, Jake Mulvaney, Faansie Peacock, Morné Pretorius, Nick Theron, the Mpumalanga Tourism and Parks Agency and Ezemvelo KZN Wildlife are thanked for sharing their sightings data with us, and for assistance with field work. Lizanne Roxburgh, Samantha Nicolson and Mark Robertson are gratefully acknowledged for their assistance with Species Distribution Modelling. Three anonymous reviewers greatly improved the content of this manuscript.

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