Density of pied crows Corvus albus in two of South Africa's protected areas

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SHORT COMMUNICATION

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Density of pied crows *Corvus albus* in two of South Africa's protected areas

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1 | INTRODUCTION

Concerns about the growing pied crow *Corvus albus* population in southern Africa over the last 30 years (Cunningham et al., 2016) stem from the potential impacts on other species. For example, reports have suggested pied crows are a key predator of the IUCN endangered geometric tortoise *Psammobates geometricus* (Fincham & Lambrechts, 2014), as well as being nest predators and/or scavengers of bird species (Sensory Ecology, 2013), including critically endangered African white-backed vultures *Gyps africanus* (Johnson & Murn, 2019). Pied crows are also a cause of concern to some domestic livestock farmers (Pisanie, 2016). Combined, this impact, and fear of impact, has led to pied crows being labelled as 'native invaders' (Cunningham et al., 2016)—a native species being labelled with the derogatory term of 'invader' for prospering under a global shift towards ecological degradation and human impact (Adelino et al., 2017; Dean & Milton, 2003; Joseph et al., 2017).

Despite concerns about pied crows, little is known about their actual impacts on other species, or about their general ecology; key components of assessing the effectiveness and approach for any management options. Clearly, there is a need for research to understand the existence and/or degree of threat posed by pied crows to other bird species in South Africa (BirdLife South Africa, 2012), and also more research into their ecology (Fincham & Nupen, 2016; Fincham et al., 2015). Here, we present estimates of pied crow densities in two protected areas within the Northern Cape Province of South Africa during the pied crow flocking period over winter (June to August). These estimates can provide a basis for continued monitoring of the population, inform local-scale management and build upon the existing population density literature to improve the evidence base around pied crows.

2 | METHODS

The study was conducted between June and August 2015 at Dronfield Nature Reserve (28.64S, 24.80E) and Mokala National Park (29.17S, 24.32E), both located near Kimberley, South Africa. We conducted road transects in Dronfield and Mokala and first developed a distance density function to determine how the probability of spotting pied crows changes with distance away from the observer along these transects. We then use this distance density function alongside a density surface model to predict pied crow densities over space.

In total, we established four road transects at each site, overlapping the majority of each site's extent and habitat types (Figure 1). As a result, site selection was non-random. Transects ranged in length from 4.5 km to 13.9 km. Transects were sampled by one observer (TFJ) in a car travelling between 20 and 30 km/h. The observer was highly competent at identifying pied crows, both in flight and in perching. When a pied crow was detected, we stopped the car and recorded crow frequency and the perpendicular distance (in metres) between the crow(s) and the transect (i.e. distance sampling). We opted to measure distance between the observer and the pied crows as a categorical bin, instead of continuously, with the following values: 0–25 m, 25–50 m, 50–100 m, 100–200 m and +200 m. We tested

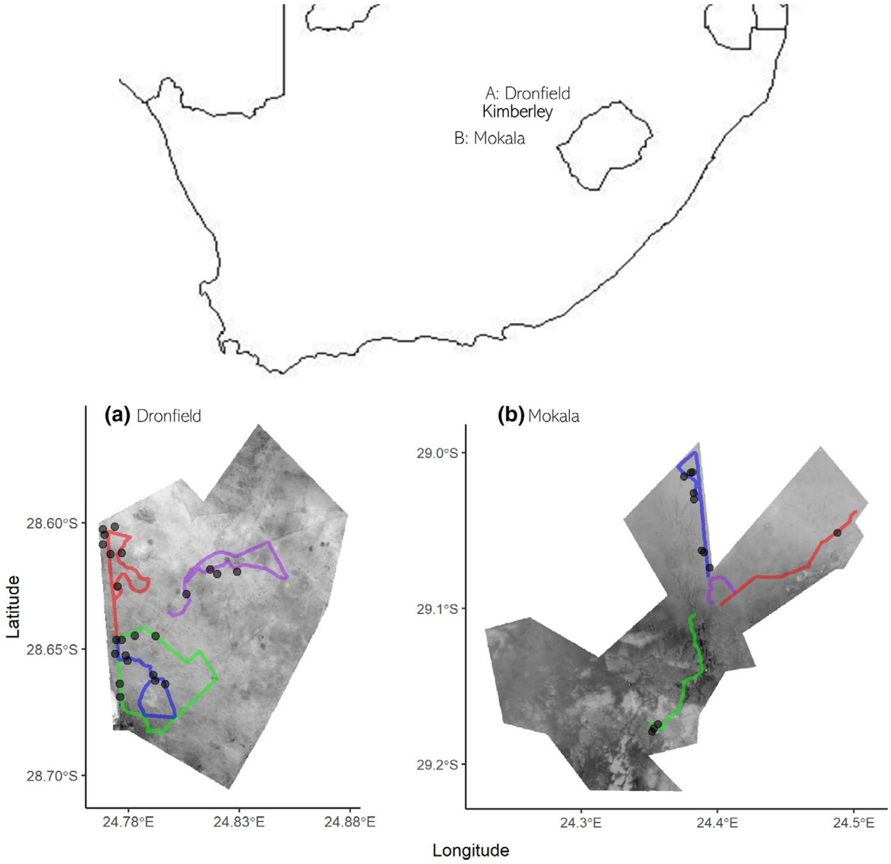

FIGURE 1 Transect routes (coloured lines) and associated pied crow detections (points) in Dronfield (left) and Mokala (right), and their position within South Africa (top). Routes are displayed over a 30-m resolution raster of normalised difference vegetation index (NDVI) ranging from 0.01 (light grey) to 0.15 (dark grey)

the observer's ability to correctly identify these distances in different habitat types prior to data collection. As transects were non-linear, turning the vehicle at 90° angles around corners risked double counting the same individual/group of crows. In the field, if we suspected we may have double-counted, we instantly ignored the sighting; however, we also retrospectively reviewed the location and timestamp of all observations prior to analysis to explore whether it was plausible that the observation could be a double count. From this, we found two observations that may represent a double count and removed them from the study. Specifically, the two potential double counts had a similar number of pied crow individuals, and both were within 1 km and 10 min of the previous observation/original count.

When multiple crows were observed, we only recorded the distance to the first crow spotted, which admittedly may introduce bias that suggests our density values (see results) are underestimated. However, as groups of pied crows were often closely aggregated, and because distances were binned (so individuals would often fall within the same bin regardless) instead of measured continuously, we expect the impact of this bias to be minimal.

Using the distance sampling data, we developed a detection model using the Distance R package (Miller et al., 2019). However, before running this model, we noticed that the 25–50 m distance bin had more observations than the 0–25 m bin, which would not be expected in a distance sampling study, as one of the core assumptions is that species at a distance of 0 m would be detected, and the detection probability will then decline accordingly with distance from the observer. We believe the higher frequency of values in the 0–25 m bin to be a random artefact in the data, rather than a methodological flaw, but regardless, we opted to concatenate the 0–25 m and 25–50 m bins into a larger 0–50 m bin. This left four bins: 0–50 m, 50–100 m, 100–200 m and +200 m—right truncated at 400 m, which we deemed the maximum limit by which we could accurately identify the species without a higher magnification scope. In our final model, we included four covariates that could influence detection: site—where crow detectability would vary between sites (Dronfield and Mokala); habitat—are individuals within grassland, savanna, or shrubland; mode—are pied crows flying or perching; and time—the absolute difference in time between the observation and midday, where we would expect detection to decrease with hours since midday. We also attempted to include: NDVI (normalised difference vegetation index)—where crow detectability may be lower in greener areas (higher NDVI); and BSI (bare soil index)—where crow detectability will be greater in areas with more bare soil—but the inclusion of these variables prevented the detection model converging, and so these two variables were excluded. We extracted 30-meter resolution NDVI and BSI data from Landsat 8 imagery (USGS, 2021).

To link the distance detection model with the spatial density surface model, we first split the transect routes into segments. In each segment, we can then assess the likelihood of observing a pied crow relative to the effort of sampling (segment length in metres multiplied by the number of times the transect was repeated). When splitting the transects into segments, we set a maximum segment length of 100 m, but segments ranged in length from this maximum all the way down to ~10 m. We selected the 100 m maximum segment length as the habitat can be highly heterogenous in places, and we wanted to align these segments to the high resolution (30 m) NDVI and BSI data. In each segment, we recorded the number of individual pied crows recorded, the latitude and longitude, NDVI, and BSI. Using this data set, we modelled the number of pied crows against a smoothing term of latitude and longitude, and linear terms of NDVI and BSI. We wanted NDVI and BSI in the density surface model, as the NDVI and BSI profiles for each reserve over the winter months broadly characterise core habitat features. High NDVI values and low BSI values in the reserves describe dense shrub-like habitat, whilst low NDVI values and high BSI values describe arid-grasslands with sparse acacia trees. NDVI and BSI are highly correlated (Pearson's correlation = 0.8), which may lead to inflation of model standard errors due to multicollinearity. However, as the core purpose of the density surface model was to predict density over space, we prioritised the improved prediction of using both terms, and compromised our ability to detect significant model parameters. We used the density surface model to predict pied crow density (individuals/km^2) across a 30-m resolution prediction grid of latitude, longitude, NDVI and BSI. We only predicted over the areas of each site that were covered by transects (i.e. the maximum rectangular extent of the transects), for three main reasons: (1) Extrapolation can be unreliable; (2) Our density surface model only includes two ecologically relevant spatially defined terms (NDVI and BSI) that could be projected over—both of which are only moderately effective at predicting pied crow abundance (see below); and (3) our most extreme values occur at the edges of the prediction grid which may not scale or project well through extrapolation, especially given point 2.

3 | RESULTS

Each transect was repeated between seven and 14 times, with a total transect sampling distance of 969 km. In total, pied crows were detected 38 times, with 66 individuals (not necessarily unique) recorded. Pied crows were detected on seven of the eight transects; they were not detected on Mokala-purple (Figure 1). Pied crow detection probability declined sharply after the 50–100 m distance bin (Figure 2).

We estimate a pied crow density of 0.20 individuals/km^2 in Dronfield and 0.19 individuals/km^2 in Mokala. These estimates are variable over space, with distinct density clustering and varying levels of uncertainty (Figure 3). For the sampled areas, we estimate an abundance of 14 individuals in Dronfield and 29 individuals in Mokala. In Dronfield, we found no evidence of an association between pied crow density and NDVI (coef = −34.4, $p = 0.46$; Figure 4) or BSI (coef = 15.9, $p = 0.57$). However, in Mokala, NDVI was negatively associated with pied crow density (coef = −86.9, $p = 0.002$; Figure 4) and BSI had a positive association with pied crow density (coef = 42.0, $p = 0.045$), suggesting there is some evidence that pied crow densities are greater in Mokala's grassland habitats. Notably, the areas with greatest densities in both Dronfield and Mokala are in close proximity to human settlements. Overall, our density

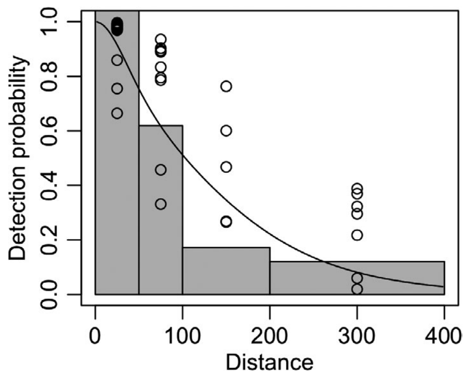

FIGURE 2 Pied crow detection probability at perpendicular distances (in metres) from transect routes in two protected areas of South Africa. Points represent the detection probability at the mid-point in each distance bin

surface models explained 12.5% and 24.0% of the overall deviance in Dronfield and Mokala, respectively—suggesting a low-moderate predictive accuracy.

4 | DISCUSSION

We present research into the ecology of pied crows by providing initial density estimates for two protected areas in South Africa, and offer insight into how crow density may be affected by habitat (i.e. NDVI and BSI).

One limitation to our estimates is the bias we introduced by conducting road transects instead of more robust line sampling. This recognition is important because pied crows are known to associate with human infrastructure like roads (Dean & Milton, 2003; Joseph et al., 2017), and so sampling with road transects may over-represent the densities. However, the roads we used are not conventional tarmac surfaces, and are instead dirt/sand/gravel tracks that are very infrequently used; it is plausible the observer's car was one of a handful vehicles on that track in a given day. Although we cannot know how the road bias has influenced our density estimates, we would argue the impact is likely to be minimal. Furthermore, our density estimates for pied crows are broadly similar to the mean density of their genus conspecifics that have been assessed through distance sampling (mean density for *Corvus* species in TetraDensity (Santini et al., 2018) is 0.32 individuals/km^2 [standard deviation = 0.43, $N = 22$]).

Our finding that pied crow densities in Mokala were negatively associated with NDVI and positively associated with BSI suggests that densities are greater in areas dominated by grassland not shrubland. This is surprising as in previous work, pied crow relative abundance (reported rates) was high and increasing in shrubland (Cunningham et al., 2016). One possible explanation is that this density-NDVI and density-BSI association is confounded, as Pied Crows within both sites tended to occur near human settlements, where NDVI would be low and BSI would be high. Suggesting its plausible that pied crows may simply occur at higher densities within less-green and more-arid environments, simply because these environments

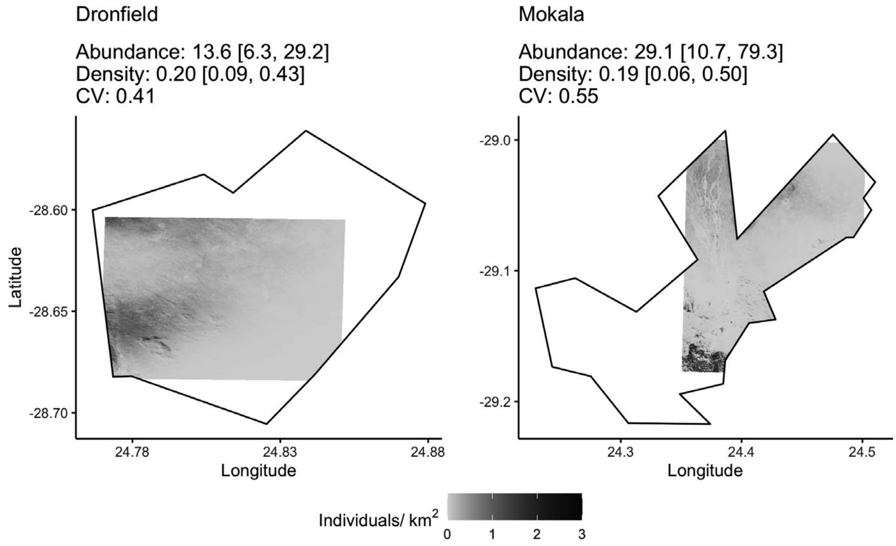

FIGURE 3 Pied crow densities' (individuals per km^2) within Dronfield (left) and Mokala (right). Density projections are trimmed to the maximum spatial extent of the transect routes (see Figure 1). Within each protected area, we describe the mean estimated total abundance and density per km^2 [with their 95% confidence intervals]. We also report the total coefficient of variation (CV) within each density projection, which is the combination of the CV from the detection and density surface models. Colour shading is limited to a maximum of 3 individuals/km^2 to reduce the effect of a small minority of outliers on the visualisation

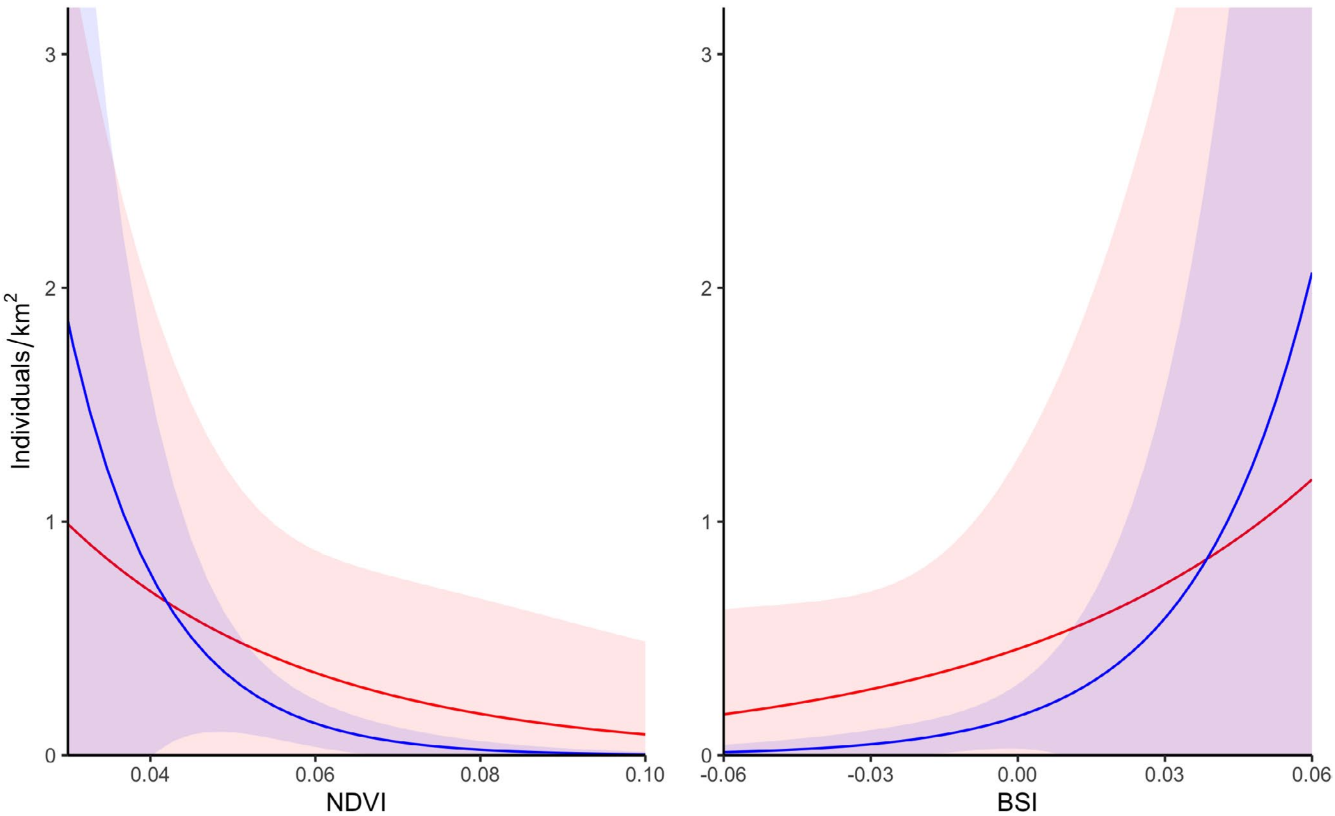

FIGURE 4 Marginal effect of normalised difference vegetation index (NDVI) and bare soil index (BSI) on pied crow density within Dronfield (red) and Mokala (blue). Coloured ribbons represent the 95% confidence intervals. *X*-axes cover the full range of NDVI and BSI values across Dronfield and Mokala

tend to also represent human landscapes. Similarly, the lack of effect for NDVI and BSI in Dronfield could be driven by edge effects. On the western border of Dronfield is the N12 highway (a source of roadkill) and Kamfers Dam (home to thousands of breeding lesser flamingo), both of which could be inflating pied crow density estimates on Dronfield's western edge, nullifying our ability to detect habitat-based density estimates within this site. Further analysis is needed to understand pied crow habitat associations more clearly, which would improve the predictive capacity of density models and the management information they can provide.

Pied crows present an important dilemma in African conservation and land management. However, making evidence-based decisions around pied crow management are constrained by a gap in knowledge of pied crow ecology and we think more work is still needed. Any basis for managing pied crows must be well supported by strong evidence showing their impact on the ecological community, any financial impact on landowners, and the potential impact of management interventions on the status and ecology of pied crows.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

AUTHOR CONTRIBUTIONS

TFJ led the design, collected and analysed the data, and wrote the first draft. CM supervised design and contributed critically to manuscript drafts.

PERMISSIONS

DeBeers and South African National Parks provided permission and access to field sites. The project was completed under South African National Parks registered project BOTA1024 and approved via SANParks' Animal Use and Care Committee permit BOTA1024(13–11).

DATA AVAILABILITY STATEMENT

All data and code to reproduce the analyses are available at https://github.com/GitTFJ/piec_crow_density_dronfield_mokala.

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