The Movement and Landscape Use of Blue Cranes in the Western Cape

In partnership with

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Acknowledgments

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Abstract

The Western Cape population of Blue Cranes (*Anthropoides paradiseus*) is the largest and most stable population for the species**.** The population is primarily threatened by high mortality due to collisions with power-lines and the development of wind farms. Yet, little is known about how this population uses the agricultural landscape and their movements. Thirteen Blue Cranes were fitted with trackers to collect Global Position System data and tracked for 3 – 18 months in the Overberg region of the Western Cape. With the provided spatial-temporal information, I estimated the home range size, daily flight distances, and distance travelled throughout the day of breeding and non-breeding cranes to determine whether the breeding status/season influences their ranging behaviour. There was no significant difference of the home range size between breeding cranes and non-breeding cranes ($p > 0.05$). There was also no significant difference of the home range size of breeding cranes between their seasons ($p > 0.05$). Breeding cranes travelled significantly shorter daily flight distances than non-breeding cranes ($p < 0.05$). Breeding cranes also travelled significantly shorter daily distances during the breeding season than the non-breeding season ($p < 0.01$). All cranes, regardless of breeding status or season, travelled further distances in the morning, decreasing distance during the midday and early afternoon with an increase in the late afternoon. Breeding cranes travelled shorter distances throughout the day than non-breeding cranes during the breeding season ($p < 0.001$). Lastly, breeding cranes travelled significantly shorter distances throughout the day in the breeding season than the non-breeding season ($p < 0.001$). From this study the results suggest that factors other than breeding status influence the ranging behaviour of these cranes. Factors such as the availability of roost and forage sites, the agricultural landscape of the Overberg and the presence of other Blue Cranes could also affect ranging behaviour. Although this study does not give clear guidelines on the movement of the population, it establishes a baseline for further studies into factors that affect their ranging behaviour and can still be used to aid in conservation strategies for the species. Future studies should focus on recording their time budgets, including overnight GPS fixes and assessing ranging behaviour over multiple years.

Keywords: ranging behaviour, breeding activity, home range, daily distance

1. Introduction

1.1. Land transformation from natural habitat to agricultural lands

Bird populations are influenced by how their preferred habitat is distributed throughout the landscape, more specifically the vegetation composition and structure of the habitat (Knopf *et al*., 1988). Extensive land use by humans has transformed the functioning and structure of many terrestrial ecosystems, with the most notable land use changes resulting from crop agriculture, livestock farming, and commercial forestry (Allan *et al*., 1997; Happold 1995). Due to these land use changes, many widely distributed habitats have become highly fragmented, resulting in many species living in landscapes within the matrix of human land use. Some species have benefited from these changes, whereas others have been threatened by this fragmentation and loss of habitat.

1.2. Grassland biome transformation in South Africa

The conversion of natural habitat to agricultural lands and the intensification of agricultural practices is widely acknowledged to be a principle cause of global biodiversity loss and is especially prevalent in the grassland biome (Neke and Plessis, 2004; Soulé, 1991; Tscharntke *et al*., 2005). In South Africa, large expanses of grassland have been modified by cultivation, livestock grazing or natural fire cycles (Rutherford and Westfall, 1994). Much of the grassland biome in South Africa is highly productive agriculturally with flat terrain and deep soils, promoting extensive agricultural transformation. Most grassland areas that are suitable for forestry lie within the higher rainfall areas of the east of South Africa, where many high biodiversity areas have been cleared for pine and eucalyptus plantations (Cowling & Hilton-Taylor, 1994; Tarboton, 1992). The rich species, community and ecosystem diversity within South Africa's grassland biome contains globally significant plant endemism (Cowling and Hilton-Taylor, 1997), about half of the nation's endemic mammal species, and 10 of 14 of it globally threatened bird species (Collar *et al*, 1994; Reyers & Tosh, 2003). The extensive habitat loss and fragmentation of grasslands has led to the biome being classed as critically endangered in South Africa (Reyers *et al*., 2001; Macdonld *et al*., 1993), linked to severe decreases in the species diversity of plants, insects and other animals.

The Overberg landscape is characterized by coastal plains and low rolling hills, with a mean annual rainfall of 450 mm. Before the mid-1900s, the Overberg was dominated by shrubby renosterveld and fynbos vegetation. It was predominantly used for grazing of cattle and sheep, until the 1940s when there was a shift from grazing lands to cereal croplands and pastures (Mustart *et al.*, 1997). This shift in land use and an increase in alien invasive species, led to more than 95% of the natural renosterveld and fynbos to be transformed (Marnewick *et al*., 2015; Mustart *et al*., 1997). Most of the Overberg landscape is now a mosaic of wheat, barley, oats and canola croplands and pastures that still provide habitat for bird species (Dayaram *et al.*, 2017; Kemper *et al*., 1999; Marnewick *et al*., 2015; Mucina and Rutherford, 2006; Young *et al*., 2003). In South Africa, there are areas called International Bird and Biodiversity Areas (IBAs) which are of global or regional conservation importance identified using birds. There are currently 122 IBAs in South Africa that spans over 14 million hectares with over 60% of that area unprotected (BirdLIfe International, 2018). Landscape transformation can be beneficial or detrimental to bird species, but the Blue Cranes' adaptation to the agricultural landscape can illustrate that the need to protect untransformed habitats in not necessary for some vulnerable bird species.

Conservation traditionally focused on untransformed habitat, but this approach has been recognized as inadequate as much of the world's biodiversity is found in transformed landscapes, especially agricultural lands (Pimentel *et al*., 1992). While land conversion and intensification of agriculture can be major threats to species survival, agricultural areas can also provide abundant food resources for animals, encouraging conservation planning for biodiversity on agricultural lands as a key research topic (Macfadyen *et al.*, 2012).

1.3. Crane conservation

Of the world's 15 crane species, 11 are classified by the IUCN as threatened, primarily due to habitat loss, human activity, climate change and collisions with infrastructure (Harris and Mirande, 2013). Most crane species are dependent on wetlands when breeding, but all species, except for the Siberian Crane (*Grus leucogeranus*), frequently forage in dryland habitats during the non-breeding season (Johnsgard, 1983). The Blue Crane *(Anthropoides paradiseus)* has the most restricted range of all cranes and is near-endemic to South Africa (McCann *et al*., 2007; Urban, Fry & Keith, 1986) with a very small population in northern Namibia (Allan, 1997,

Hockey *et al*., 2005). Historically, the species used to be largely dependent on the grassland biome for its survival in short, dry grasslands at high elevations, but now the species largest population is in the fynbos biome. Blue Cranes favour these habitat types because they ensure sufficient breeding productivity while also allowing good visibility to detect potential terrestrial predators (Bidwell, 2004; Morrison and Bothma, 1998).

Blue Cranes are partial migrants that make local, seasonal movements across elevational gradients and can be resident or locally nomadic in some areas (Barnes, 2000; Hockey *et al*., 2005; Vernon *et al*., 2002). A recent study demonstrated that individually-marked Blue Cranes have high regional fidelity, with <5% of cranes observed to move between the Overberg and Swartland regions in the Western Cape (van Velden *et al*., 2016a). This study also found that many birds banded as chicks recruit as adults to their natal area. Blue Cranes are monogamous, and mated pairs usually stay together until one dies (Meine and Archibald, 1996). This strong pair bond is formed once a pair has had a successful breeding attempt (Tacha *et al*., 1992). This species breeds in natural grass- and sedge-dominated habitats, preferring secluded at high elevations. However in the Western Cape, they use lowland agricultural areas, such as pastures and crop fields when stubble is available after harvest, avoiding natural fynbos vegetation because it is thought that crop fields after harvest most resemble their natural grassland habitat (Barnes, 2000; Allan, 1993).

Blue Cranes breed between September and May with a peak in November. The mature birds are often seen in pairs while the immature birds often flock together in large groups (Urban *et al*., 1986). Flocks are highly congregatory, usually comprising 20-50 individuals, with occasionally large flocks of hundreds to thousands of birds (Hockey *et al*., 2005). Mature birds will pair off during the breeding season and establish breeding territories (McCann *et al*., 2001). By looking at the movements of these cranes across different breeding seasons and based on their breeding status, their home range and possible movement patterns can be established. This information can help build information about the essential areas and initiate studies in the habitat usage in the fynbos biome for the crane population in the Overberg.

1.4. Distribution of the Blue Crane

The last global population estimate of the species was around 25,000 birds with >99% in South Africa; <50 occur around Etosha Pan in northern Namibia (McCann *et al.* 2007). Within South

Africa, Blue Cranes are found predominantly within three areas. One population occurs in the Northern and Eastern Cape provinces, which historically was the stronghold for the species, but the population has experienced decline due the loss of their breeding grassland habitat. Another population is centered at the junction of Mpumalanga, Free State and KwaZulu-Natal provinces. Lastly, there is the population that occurs in the fynbos biome of the Western Cape province. This population is well adapted to the agricultural wheat belts of the Swartland and Overberg regions in the southern Western Cape (Barnes, 2000). Blue Cranes are attracted to agricultural fields where they feed on grain, such as wheat and maize, that has just fallen or crops that were recently germinated. They also flock to pastures to feed on the food set out for small stock such as sheep. It has been recorded that approximately half of the world population is in the Western Cape, followed by the population in the Central Karoo with 42% and the eastern grasslands with 10% remaining in the former stronghold of the eastern grasslands (McCann *et al*. 2007). However, it has recently been reported that the population has increased to ~17,000 (Lynch and D'Alton, pers. comm.).

1.5. Threats facing the Blue Crane population

The numbers in the Western Cape province have increased, but the global population has decreased by 50% since the 1970s primarily due to poisoning, collisions with power-lines and fences, and loss of its grassland breeding habitat due to afforestation, agriculture, mining and development (McCann *et al*., 2001). The decline is rapid enough to have the species classified as Vulnerable on the IUCN Red List of Species for Southern Africa and on the global red list (BirdLife International, 2008; IUCN, 2016).

Population modelling suggests that even a small increase in adult mortality rates or a decrease in breeding productivity from the current situation could result in a rapid decline of the population (Shaw *et al*., 2010; McCann *et al.*, 2001). There are many threats to the species currently, but collisions with power-lines, is arguably the principle cause of mortality. Currently, it is estimated that 12% of the Western Cape population is killed annually by these collisions (Kotoane, 2003; Shaw *et al*., 2010). The area is also one of the primary hotspots for wind farm developments in the country (with over 560 wind turbines active), which had resulted in an expansion of the power-line network in the area.

Besides power-line collisions, Blue Cranes in the Western Cape are perceived as problematic by some farmers for damaging their crops and can be targeted by poisoning (van Velden et al. 2016b). They can also become unintended targets of farmers who do not view Blue Cranes as problematic that target vermin, guinea fowl and geese that destroy their crops (Hockey *et al*., 2006; Lynch and D'Alton, pers. comm., Taraboton, 1992; Vernon *et al*., 1992). There is also a growing concern of the increasing number of small farms being consolidated into larger ones in the Western Cape. Multiple farmers work together to consolidate small farms, moving away from traditional farming to mechanized farming on a large scale. This shifts the focus to growing more crops and moving farm animals off the land, in turn getting rid of the pastures that Blue Crane utilize to roost and forage (Lynch and D'Alton, pers. comm.). Lastly, the Western Cape is an area that scientists believe will be heavily impacted by climate change, which will likely make the area less suitable for current crops (Altwegg and Anderson, 2009). Less rainfall due to climate change in the region can push farmers to change from grain farming, specifically wheat, to crops that require less water. Blue Cranes have adapted to the specific crops and their seasonal cycles that make up the agricultural landscape in the region at present, and any changes to this could significantly impact the future of the population.

1.6. Rationale, objectives and hypotheses

Blue Cranes have been studied in both the grassland and fynbos biomes of South Africa, but most research has focused on habitat choice (Allan, 1995; Bidwell, 2004; Morrison, 1998; Mmonoa, 2009) and threats (e.g. Allan and Ryan, 1996; Shaw *et al*. 2010). Little is known about the factors that could influence their movement patterns and ranging behaviour, such as their ecology and the environment (e.g. van Velden *et al*., 2016). The large number of threats facing Blue Crane is a major concern and the Blue Crane is a significant component of South Africa's biodiversity and heritage. This project will help us become more informed about the stronghold population of Blue Cranes in the Overberg by providing baseline information on their movements and ranging behaviour based on their breeding status and breeding season. This information also gives us a more precise assessment of the areas and landscapes that are important to this population and where to focus future studies within the Overberg for at the moment there is no explanation as to why home ranges would be smaller for breeding cranes.

In this study, I use the GPS data from thirteen Blue Cranes fitted with trackers in the Overberg combined with observational data to give more insight on the home range sizes, daily movement distances, roost sites, foraging sites and movement patterns of Blue Cranes in the Western Cape. The hypotheses examined in this study were that (i) the home range size and home range use of breeding cranes would decrease significantly during the breeding season when compared to their non-breeding season and non-breeding cranes, (ii) that these cranes show high regional fidelity in the Overberg region and (iii) that not only their physiology, but also environmental factors can be indicators to their ranging behaviour (Nesbitt and Williams, 1990; McCann and Benn, 2006). This study and any future research on the movements on the Western Cape population will be useful in creating a conservation strategy of what areas need to be conserved for the future survival of the species.

Methods

2.1. Study Area

The study was conducted in the Overberg region of the Western Cape, South Africa, which covers about 12,850 km^2 and extends from 19 to 21°E. The region is bounded by mountains of the Cape Fold Belt (Hottentot-Holland mountains in the west and the Riviersonderend Mountains in the north); the Atlantic and Indian Oceans in the south and the Breede River in to the east (Figure 1).

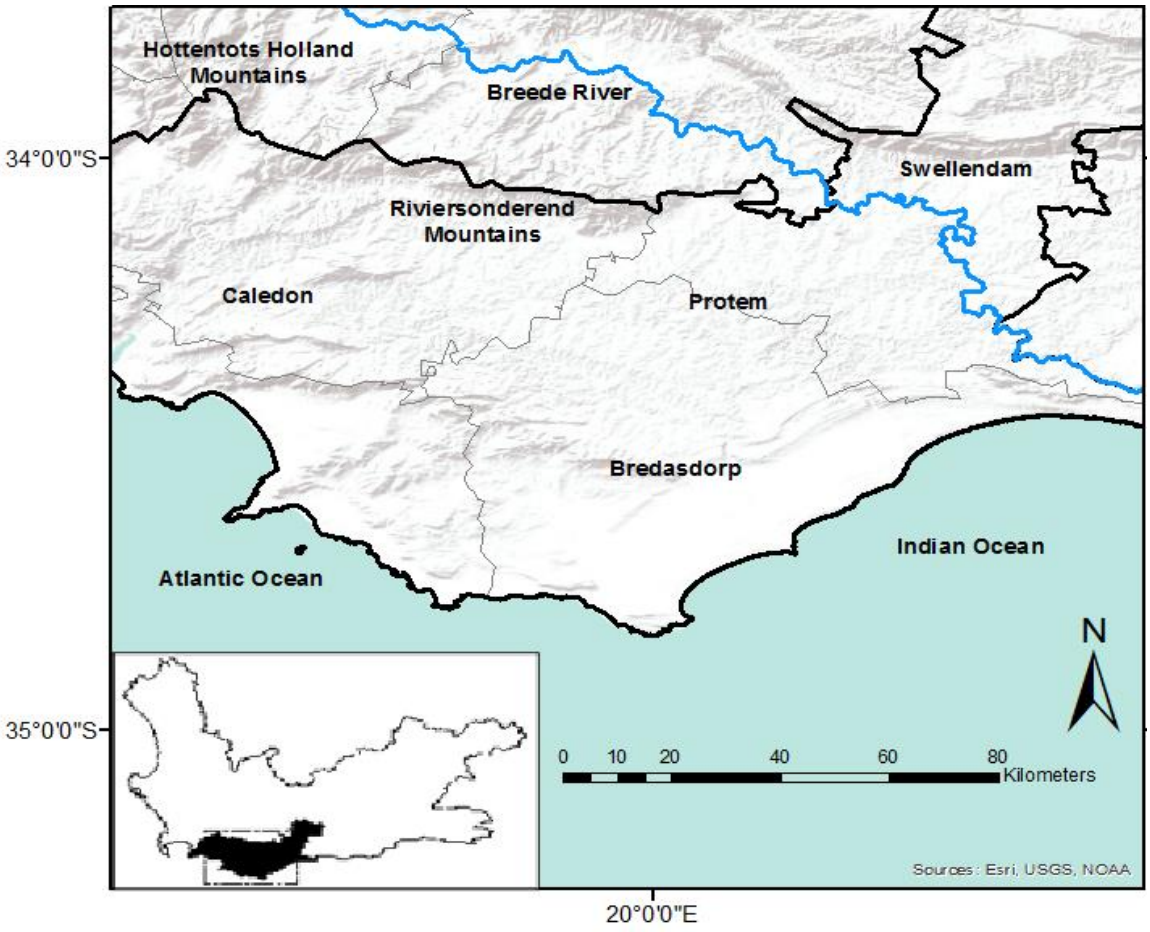

Figure 1. *Study area in the Overberg region of the Western Cape, South Africa.*

2.2. Capture and Marking

Cranes were caught outside the breeding season near the feeding troughs for livestock where flocks of cranes were observed foraging. They were caught using long lines of toe noose traps, baited with grain. This technique has been widely used to catch large terrestrial birds and is generally deemed to be safe provided birds are rapidly caught after becoming ensnared (Shaw *et al.*, 2014).

Crane capture and marking procedures were approved by and through an internal ethics review process within the Endangered Wildlife Trust (EWT) and was reviewed by the Conservation Management Team at the EWT, headed by Dr. Harriet Davies-Mostert (reference:1/2/1/6/5/ S). The ethics review was accepted and approved in August 2015 for the year of 2015-2016 and 2017. Capture and handling of Blue Cranes and the fitting of tracking units were executed under the Endangered Wildlife Trust's African Crane Conservation Programme granted by Cape Nature, South Africa (permit No.: 0056-AAA041-00114, 0056-AAA041-00182). Apart from the first 6 cranes caught, all individuals were fitted with a unique colour ring combination to allow subsequent identification should they lose their tags.

Thirteen Blue Cranes were fitted with one of two models of dual powered GPS-GSM backpack trackers (Ecotone Telemetry Inc., Sopot, Poland; BioLog Wildlife Tracking, KZN, South Africa. The devices weighed 90 g, which is within the recommended limit of < 3% of a bird's body weight (Phillips *et al*. 2006). Blue Cranes on average weigh between 4.5 and 5.1 kg (Ginn *et al.* 1989; Hockey *et al.* 2005). The trackers had a solar panel and a lithium battery as a back-up power source. Six were fitted in July 2016 and seven more in August 2017. All cranes were captured and fitted across five sites in agricultural fields in the northeast Cape Agulhas municipality between the two major towns Bredasdorp and Protem of the Overberg region. All cranes fitted with trackers were adults, with the exception of one juvenile (Table 1). The age class of these cranes was determined by the coloration of the head feathers and the presence or absence of long wing plumes. Adult Blue Cranes are a pale blue-grey colour becoming darker on the upper head, neck and nape. They also have long wingtip feathers that trail on the ground. Juvenile cranes are slightly smaller and slightly lighter, with their heads being a tawny color and no long wing plumes. In all cases, GPS-GSM backpacks trackers were attached on the cranes'

backs using 8mm Teflon Ribbon to make a harness around the birds' breasts and bellies. The Teflon ribbon was sewn together with dental floss and the stitching sealed with super glue.

Where possible, less than 2 ml of blood was taken per individual for sex determination, using the Avian sexing kit supplied by Molecular Diagnostic Services (MDS Pty Ltd., Westville, South Africa) for sample collection. Genetic sex determination was performed by MDS using nucleic acid amplification procedures. Blood samples were only collected for six of the thirteen cranes so using sex as a possible indicator of ranging behaviour was excluded from analysis.

The GPS-GSM trackers were programmed to record GPS (Global Positioning System) positions every two hours between 06:00 and 12:00 and every three hours between 12:00 and 18:00. No locations were recorded at night. Time, the instantaneous speed and altitude was also recorded at the time of the recorded position. The tracker on Crane 4 fell off the crane originally fitted in July 2016. It was retrieved in January 2017 and refitted to a new adult crane (Crane 10) in August 2017. In addition, the tracker for Crane 3 failed to work after about a month when the trackers were fitted. Trackers that remained function recorded data on the regular fixed schedule

2.3. Observational data

Observational data was collected between September 30th and October 20th, 2017. Observational data collection attempted to track down as many of the fitted cranes as possible for visual confirmation of their breeding status, roost sites and forage sites. Visual confirmations were conducted by looking the location pings of individual birds from the day prior and at 6AM of the same day. Tracking the birds started at 6 AM after seeing the same day 6 AM location ping. I would travel to the location using GPS and look for the crane fitted with the tracker to be observed. If the fitted crane is spotted, GPS coordinates, elevation, landscape or surroundings and number of cranes in proximity if they are in a non-breeding flock were recorded. Observing their breeding status in the field allowed me to determine which cranes were breeding for calculation of home range size and home range use between seasons. Not all cranes were able to be observed in the field and even cranes observed to be non-breeding were not guaranteed to have never bred for they could have had a failed breeding or skipped this year. Cranes that were observed in a breeding pair were labeled as breeding, cranes that were observed in large flocks were labeled as nonbreeding and those that I was unable to observed were labeled unknown. When a crane with a tracker was found, descriptions of the location were recorded, which

included date, time of observation, elevation, habitat, the number of cranes present, and any other notes about the surrounding area such as crop fields, distance to the nearest powerlines, water body, buildings, etc. Roost sites were determined for each individual by looking for repeats of the same location in the data during the 6:00 GPS fix (early morning). I confirmed roost and forage sites when I observed the crane at the same site on multiple days early in the morning before sunrise.

Table 1. *General information for study Blue Cranes used in this study fitted with trackers by Endangered Wildlife Trust and CapeNature between 2016 and 2017 outlining the age class, breeding status in spring 2017, when the tracker was fitted, duration of tracking.*

ID	Adult or Juvenile	Breeding Status	Start Date	Tracking Duration (days)
Crane 1*	Adult	Non-breeding	06/07/2016	551
Crane 2	Adult	Breeding	06/07/2016	261
Crane 4	Juvenile	Non-breeding	11/07/2016	161
Crane 5*	Adult	Breeding	12/07/2016	544
Crane 6*	Adult	Breeding	12/07/2016	545
Crane 7*	Adult	Non-breeding	04/08/2017	157
Crane 8*	Adult	Non-breeding	03/08/2017	158
Crane 9*	Adult	Non-breeding	04/08/2017	157
Crane 10	Adult	Breeding	05/08/2017	101
Crane 11	Adult	Non-breeding	03/08/2017	103
Crane 12	Adult	Breeding	03/08/2017	158
Crane 13	Adult	Unknown	02/08/2017	158

*Trackers that are still operational after the data cut- off date

2.3. Spatial and Temporal Analyses

Spatial analyses used GPS fixes projected to the UTM coordinate system (WGS 1984 UTM Zone 35S) for use in R Studio v.3.0.2 (R Foundation for Statistical Computing, Vienna, Austria), ArcGIS v.10.0 (ESRI, Redlands, USA). Two seasons were compared: "season" was either breeding (1 September–30 May) or non-breeding (1 June–30 August) because I expected home range size and use to vary with changes in breeding activity. The breeding season is defined as

the period between nest building in September until the chicks are fledging in May, and the non-breeding season as the post fledging period until natal dispersal upon initiation of nest building the following year (McCann *et al*., 2001). Breeding individuals and non-breeding individuals were compared for home range size and use. For all spatial analyses involving seasonal comparisons, the home range and use for breeding individuals of the breeding season and non-breeding season were compared.

2.3.1. Home Range Size

The home range of each individual was estimated using minimum convex polygon (MCP) and a kernel density (KDE) approaches. A Minimum Convex Polygon (MCP) encompasses all of an individual's GPS fixes (Calenge, 2016), which is known to overestimate an individual's home range (cf. Burt, 1943) because occasional large movements outside the core range creates outliers that are not "normal activities" (Calenge, 2016). This problem is likely sensitive to sample size, with birds tracked for longer more likely to include unusual movement events. Although MCPs tend to overestimate the actual area occupied by the individual, they provide an indication of the overall foraging area and allow comparisons with other studies.

Under the KDE model, the animals use of space is described by a bivariate normal kernel function so that it gives the probability density to relocate an animal based of the locations of the individual (Calenge, 2016). Kernel density contours were calculated at fixed 95%, 75% and 50% kernels to estimate the majority of the home range areas (95%), and the core "intensive use" areas (50%) (Fieberg, 2007). Total and seasonal home range sizes were calculated in R using the package "adehabitatHR" v.0.4.10 (Calenge, 2016) with the package "rgdal" v.0.8-16 (Bivand *et al*. 2017). The smoothing parameter was computed with the ad hoc method, trying different bandwidths until I discovered the best "href" fit to these data. I merged each individual's 95%, 75% and 50% kernel to determine the geographical areas that were overlapping each other for management planning purposes.

2.3.2. Home Range Use

Daily average distances and distances travelled at different times throughout the day was calculated in R using the package "adehabitatLT" v.0.4.10 (Calenge, 2006) with the package "rgdal" v.0.8-16 (Bivand *et al*. 2017) to process the spatial data. To quantify the extent of Blue

Crane movements, I determined the distance travelled between the time intervals that fixes were recorded for all individuals. Using R, daily distances were calculated, as the straight-line distance between consecutive fixes, providing a minimum, average and maximum daily distance. The distance between the last fix of the day (18:00) and the first fix the next morning (06:00) was divided in half, with one half allocated to each day's total distance tally. Average distance travelled per time interval was calculated to determine whether Blue Crane movements changed throughout the day. Average distance per time interval was reported as distance per hour. For the analysis, I used mean daily distances per individual/per season and mean distances per time interval per individual/per season.

2.3.3. Data Analysis

I used the "lsmeans" v.1.0-6 package (Lenth, 2016) within R to perform General Linear Models (GLMs) to explore the relationships between breeding activity status and i) home range size (S6 Table, I), and ii) daily distance and distance per time interval (i.e., home range use) (S6 Table, II, III, IV). The interaction explored whether any difference in home range size/use and breeding status was consistent. Because duration of tracking may influence the accuracy of home range size, I included the number of days each bird was tracked as a weighting term in the analyses. The number of days tracked was included as a fixed factor in the home range size/use models to control for the effect of days on distances moved, because data were not fully balanced between these variables for each individual. Individual identity was included as a random term in these GLMs to account for the independence of each individual from another.

I first compared home range and use between breeding individuals and non-breeding individuals. Then I compared home range size and use between seasons per breeding individual for each season as the response variable and fitting season as fixed factors in the model. Individual identity was again included as a random term. Non-breeding adults (n=7) were excluded from the breeding season data for seasonal comparisons. One crane (Crane 12) was only tracked during the breeding season and was also excluded from seasonal analysis due to visual confirmation of the bird breeding early immediately after capture and release. Pairwise comparisons between the interaction terms were made using the "lsmeans" v.1.10-4 package with *P* values. The Wald Chi-squared test was used, adjusted using the Tukey method, as the default for pairwise comparisons.

Due to the small sample size of our study compared to the population in the Western Cape, the kernel and MCP ranges and movements of marked birds in this study cannot be considered the foraging range of the entire population.

3. Results

3.1. Home Range Size

I obtained satellite tracking data from 12 Blue Cranes tracked for 101-551 days. In total, there were 17,978 GPS fixes between August 2016 and January 2018; 8,440 GPS fixes for the non-breeding cranes (47%) and 9,538 GPS fixes for the breeding cranes (53%). For full details of each individual tracked see Table S1.

The merged 50%, 75% and 95% kernels of breeding adults covered an area of 44.7 km^2, 97.5 km^2 and 282 km^2, respectively (Fig. S2a). The merged 50%, 75% and 95% kernels of non-breeding adults, covered an area of 221 km^2, 549 km^2 and 1,494 km^2, respectively (Fig. S2b). There was no significant difference in overall kernel range size between breeding cranes and non-breeding cranes ($\chi^2_{(1)}$= 0.9577, P = 0.3278; Table 2, Table 6).

Table 2. *A comparison of the total 95% kernel home range estimates and the Minimum Convex Polygon (MCP) ranges (mean ± standard deviation) for breeding and non-breeding Blue Cranes in the Overberg region of South Africa throughout the year.*

	Crane ID	**95% kernel range (km^2)**	**MCP range (km^2)**	**Tracking Duration (days)**
Nonbreeding	Crane 1	25.9 ± 30.2	77.5 ± 214.1	551
	Crane 4*	145.1 ± 124.3	132.8 ± 176.5	161
	Crane 7	606.2 ± 678.6	482.2 ± 883.8	157
	Crane 8	3.0 ± 3.3	2.9 ± 5.9	158
	Crane 9	36.7 ± 38.5	34.8 ± 69.9	157
	Crane 11	45.1 ± 41.5	38.2 ± 3.90	103
Unknown	Crane 13	2.6 ± 2.9	2.0 ± 4.0	158
Breeding	Crane 2	2.3 ± 2.1	3.0 ± 5.5	261
	Crane 5	3.9 ± 6.3	20.1 ± 53.4	544
	Crane 6	2.3 ± 2.9	5.6 ± 12.9	545
	Crane 10	56.2 ± 51.3	48.7 ± 32.4	101
	Crane 12	3.4 ± 4.0	6.2 ± 15.7	158

*Juvenile

Four adult cranes had both breeding and non-breeding season movement data (Fig. 1). While breeding, the cranes' home ranges were centred around their breeding site with some overlap between territories between Cranes 2 and 10, and Cranes 5 and 6 (Fig. 1a & b).

From the KDE approach, Crane 2 had decreased its home range by 66% in the breeding season (Fig. 1, Table 3). Crane 5 had the largest decrease in its home range during the breeding season, with a decrease of 95% (Fig. 1, Table 3). Crane 6 had a similar home range in the breeding season to its home range in the non-breeding season (Fig. 1a & b, Table 3), but the MCP approach shows that its total home range during the breeding season was slightly larger than during the non-breeding season (Fig. 1c & d). Crane 10 decreased its home range during the breeding season by 37% (Table 3), but the MCP approach does not show much of difference in its total home range between seasons (Fig. 1a & b) and the KDE approach shows a larger total home range in the breeding season than the non-breeding season (Fig. 1c & d). Breeding cranes home ranges did not differ significantly between the breeding (5.4±6.3 km^2) and non-breeding (17.4±15.4 km^2) season (Wald $\chi^2_{(1)}=0.16$, $P=0.69$; Table 6).

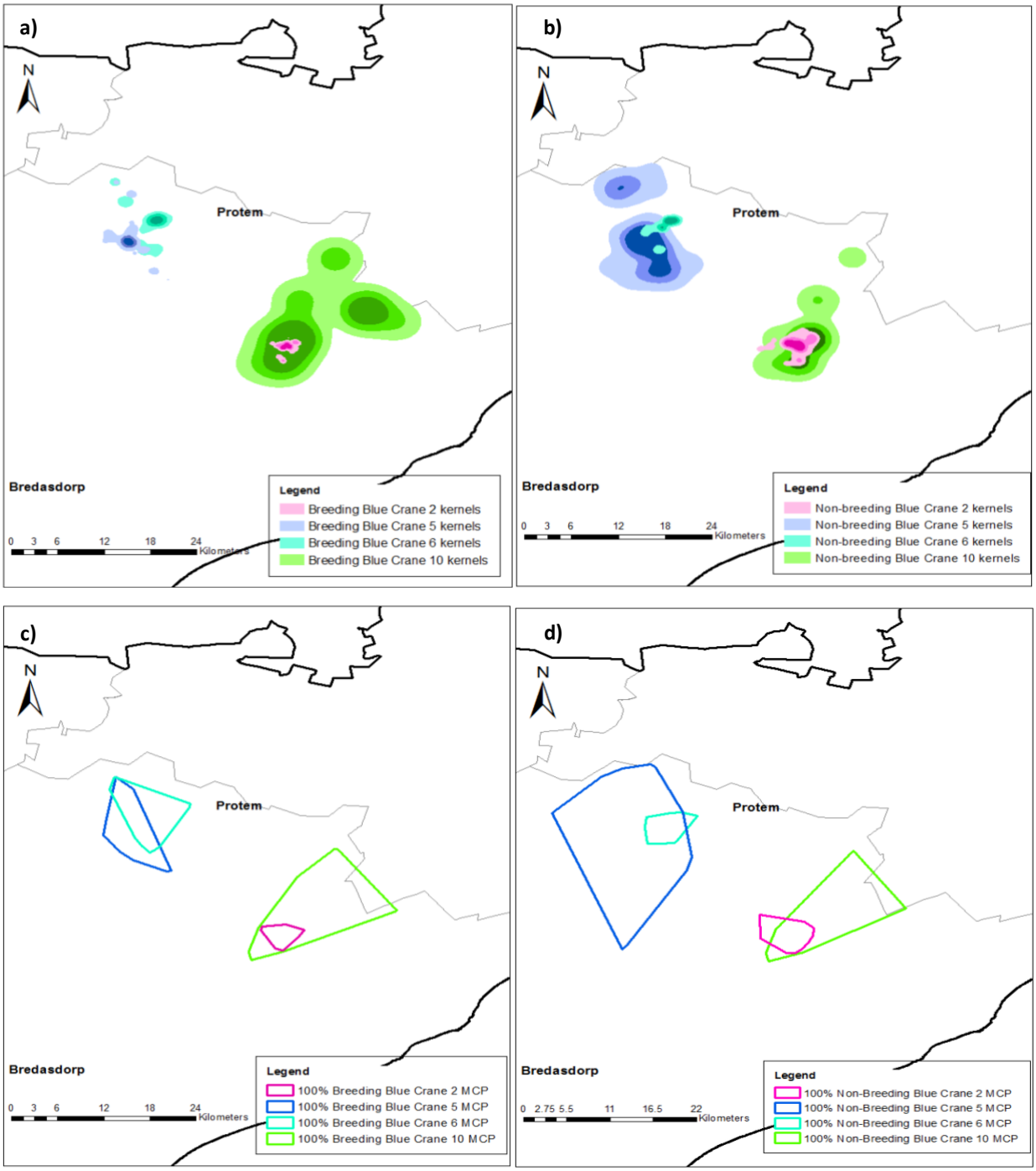

Figure 1. *Blue Crane home ranges in the Overberg region of South Africa showing 50%, 75% and 95% kernel home ranges for breeding individuals (n=4) during the a) breeding season and b) non-breeding season, and Minimum Convex Polygon (MCP) home ranges for the c) breeding season and d) and non-breeding season, indicating some overlap of home ranges.*

Table 3. *A comparison of the total and seasonal 95% kernel home range estimates in km² (mean ± standard deviation) and the Minimum Convex Polygon (MCP) home range estimates for breeding adult Blue Cranes in South Africa.*

Crane ID	95% kernel range (km²)	MCP range (km²)	Seasonal 95% kernel range (km²)	
			Breeding	Non-breeding
Crane 2	2.3 ± 2.1	3.0 ± 5.5	1.6 ± 1.4	4.8 ± 4.4
Crane 5	3.9 ± 6.3	20.1 ± 53.4	1.6 ± 2.3	36.8 ± 32.2
Crane 6	2.3 ± 2.9	5.6 ± 12.9	2.3 ± 3.1	2.4 ± 2.3
Crane 10	56.2 ± 51.3	48.7 ± 32.4	16.4 ± 18.33	25.8 ± 22.9

3.2. Home Range Use and Daily Movements

3.2.1. Daily Distance

Minimum estimates of daily distance travelled were significantly less for breeding cranes (3.1±1.1 km) than non-breeding cranes (6.8±2.0 km) (Wald $\chi^2_{(1)}$=4.113, P=0.043; Table 6). Out of the breeding cranes, Crane 5 and Crane 10 showed a significant decrease from non-breeding to breeding season by decreasing their daily distance travelled by about 50% (Table 4). Cranes 2 and 6 did not show as marked a decrease between seasons (32-37%; Table 4). There was a significant difference in daily distance travelled for breeding cranes between their breeding season (3.6±0.6 km) and non-breeding season (6.6±2.0 km) (Table 4). Pairwise tests showed that breeding cranes travelled significantly shorter distances during the breeding season than the non-breeding season (Wald $\chi^2_{(1)}$=10.33, P<0.01; Table 6).

Table 4. *A comparison of the total and seasonal average daily distances (in km) between fixes (mean ± standard deviation) of the Breeding Blue Cranes.*

Crane ID	Average Daily Distance	Breeding Season	Non-breeding Season
Crane 2	3.6 ± 0.7 km	3.2 ± 0.7 km	5.1 ± 0.9 km
Crane 5	4.1 ± 1.0 km	3.2 ± 0.8 km	6.7 ± 1.4 km
Crane 6	3.7 ± 1.0 km	3.3 ± 1.0 km	4.8 ± 1.0 km
Crane 10	6.0 ± 1.6 km	4.7 ± 1.4 km	9.8 ± 2.0 km

3.2.2. Distance Travelled throughout the day

Non-breeding cranes travelled similar distances per hour during the breeding season than during the non-breeding season (Fig. 3b & c). Breeding cranes decreased the distance travelled per hour during the breeding season from the non-breeding season (Fig. 3a & c). The distance travelled per hour throughout the day of breeding cranes varied significantly between non-breeding cranes during the breeding season and all cranes during the non-breeding season (Wald $\chi^2_{(1)}= 42.232$, $P < 0.001$), with breeding cranes travelling shorter distances per hour (Fig. 3, Table 6). All cranes during the non-breeding season and both groups during the breeding season showed a trend of decreasing the distance travelled per hour from early morning (06:00–08:00) to the early afternoon (12:00–15:00), with an increase in the late afternoon (15:00 to 18:00; Fig. 3). Movement rates at night (18:00-6:00) were the lowest overall, but still averaged > 200 $m.h^{-1}$ in all seasons (Fig. 3). Pairwise tests show that all cranes in the non-breeding season, and both groups of cranes during the breeding season travelled further distances per hour in the 06:00 to 08:00 interval than the 10:00 to12:00, 12:00 to 15:00, 15:00 to 18:00 and Overnight intervals ($\chi^2_{(4)}= 89.767$, $P< 0.001$; Table 6). All cranes in the non-breeding season and both groups of cranes during the breeding season travelled further distances per hour during the 08:00 to 10:00, 10:00 to 12:00, and 15:00 to 18:00 intervals than the Overnight interval (Table 6).

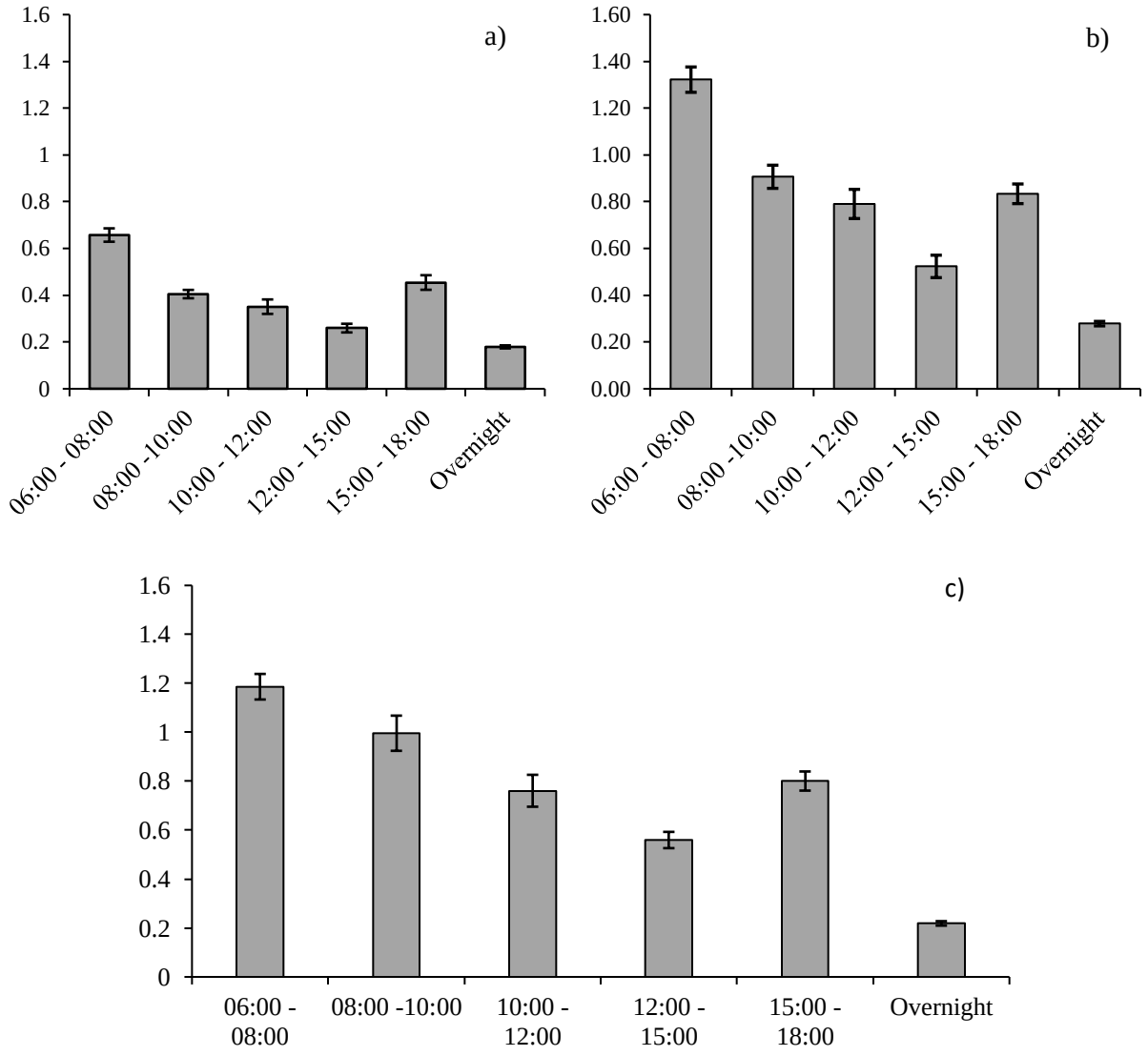

Figure 3. *The average (mean±SE) daily distance per hour travelled (km.h^{-1}) of a) breeding cranes during the breeding season, b) non-breeding cranes during the breeding season and c) all cranes during the non-breeding season by each time interval GPS fixes were recorded.*

Individual breeding cranes showed the same overall trend, travelling shorter distances/hour in the breeding season than the non-breeding season (Fig. 4; Wald $\chi^2_{(1)}$=17.117, P<0.001; Table 6). Distance/hour also varied significantly between time intervals, with greater movements in the early morning and evening than through the middle of the day (Wald $\chi^2_{(4)}$=16.629, P=0.002; Table 6). Pairwise tests showed that breeding cranes travelled significantly shorter distances/hour

per time interval in the breeding season than in the non-breeding season across all time intervals, except at overnight (Table 6).

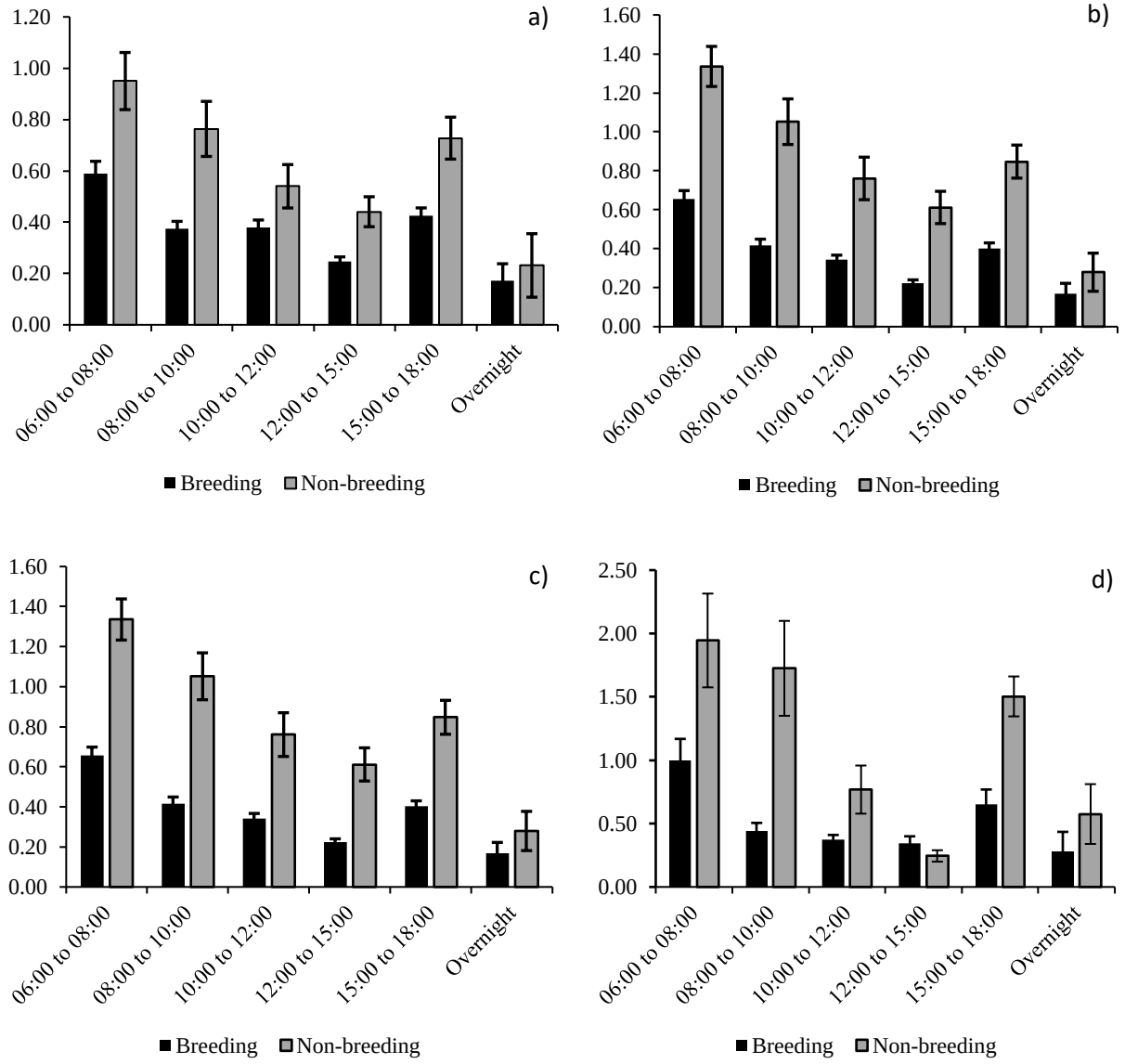

Figure 4. *The average (mean ± standard error) distance per hour travelled (in km/hour) per time interval during the breeding and non-breeding season for a) Crane 2, b) Crane 5, c) Crane 6 and d) Crane 10.*

The roost to first forage site distances of breeding cranes (1.8±2.4 km) and non-breeding cranes (4.3±4.8 km) did not vary significantly, but were close to significant ($\chi^2_{(1)}$= 3.1960, P=0.074). Crane 2 and 6 travelled slightly shorter distances in the breeding season than the non-breeding season (Table 5). Crane 2 decreased its roost to forage distance by 37% and Crane 6 by 19% in

the breeding season from the non-breeding season. Crane 5 and 10 travelled drastically shorter roost to forage site distances in the breeding season (Table 5). Crane 5 decreased its roost to forage distance by 52% and Crane 10 decreased its roost to forage distance by 49% (Table 5). Roost to forage site distances did differ significantly in their movements between the seasons of breeding cranes ($\chi^2_{(1)}$= 6.1810, P=0.013).

Table 5. *A comparison of the total and seasonal average roost to forage site distances (in km) between 0600 (roost) and 0800 (first forage site) fixes (mean ± standard deviation) of the Breeding Blue Cranes.*

Crane ID	Average Roost to Forage Site Distance Travelled	Breeding Season	Non-breeding Season
Crane 2	1.3 ± 1.5 km	1.2 ± 1.4 km	1.9 ± 1.7 km
Crane 5	1.6 ± 2.1 km	1.3 ± 1.7 km	2.7 ± 2.4 km
Crane 6	1.4 ± 2.1 km	1.3 ± 2.0 km	1.6 ± 2.0 km
Crane 10	2.5 ± 3.5 km	2.0 ± 2.9 km	3.9 ± 3.8 km

Table 6. *Results of general linear models (GLMs) fitted with home range and distance as dependent variables, individual as random effect and number of days traced was included as a fixed factor.*

Model	Response Variable	Explanatory Variable	χ^2	df	P-value
1a	Total 95% kernel home ranges	Breeding Status	0.9577	1	0.3278
1b	95% kernel home ranges of breeding cranes by season	Season	0.15609	1	0.6928
2a	Average daily distance	Breeding Status	4.1134	1	0.04254 *
2b	Average daily distance of breeding cranes by season	Season	10.3344	1	0.001306 **
3a	Average Roost to forage distance	Breeding Status	3.1960	1	0.07382
3b	Average Roost to forage distance of breeding cranes by season	Season	6.1810	1	0.01291 *
4a	Distance/hour per time interval	Status	42.232	2	<0.001***
4b	Distance/hour per time interval	Time	20.02	5	0.001239 **
4c	Distance/hour per time interval of breeding cranes by season	Season	16.4844	1	< 0.001 ***
4d	Distance/hour per time interval of breeding cranes by season	Time	26.1654	5	< 0.001 ***

4. Discussion

4.1. Home Range Size

The home range of these Blue Cranes appear to not be as significantly influenced by breeding status/season as expected. The small sample of birds tracked were largely resident, with only one bird (crane 7) showing some local nomadism within the Overberg region. This largely accords with the high regional fidelity to the Overberg reported by van Velden *et al*. (2016a). Two of the breeding cranes decreased their home range during the breeding season, with one having no change at all, and one showing a slight increase. The trend of reduction in home range size while breeding has been recorded in White-naped (*Grus vipio)* and Sandhill Cranes (*Grus canadensis)* during their incubation and chick-rearing period (Nesbitt and Williams; 1990; Liyang *et al*., 1991).

A previous study of Blue Cranes breeding in Mpumalanga Province estimated their home ranges to be 0.43±0.10 km^2 (Mmonoa, 2009), which is less than the estimates from my study. However, the home ranges in Mpumalanga may have been underestimated because they were based on a small number of GPS fixes for each breeding pair, each pair only being observed twice a week or the result of different environments (Mmonoa, 2009). Surprisingly, there was also considerable overlap of foraging areas of breeding cranes in the Overberg, challenging previous statements that Blue Cranes are territorial, solitary breeders (Hockey *et al*., 2005; Mmonoa, 2009). Cranes are territorial, but only in the vicinity of the nest and they usually don't defend feeding territories (Bennett, 1989).

It is necessary for animals to be able to distinguish their "home" and what areas have suitable food resources, water resources etc. within their home range (Wiltschko & Wiltschko, 1987). Studies have also shown that for environmental reasons, specific areas are utilized more often in one's home range than others (Burt, 1943). For this reason, it is thought that animals use cognitive maps of the landscape in order to remember where resources are located (Stamps, 1995). Remembering areas where resources are abundant can allow animals to save time and energy by using these areas repeatedly to provide their daily energy requirements without travelling large distances from their "home". For example, for Blue Cranes breeding in the Mpumalanga Province nests were found in agricultural land and in the core areas (50% kernel)

of their home range (Mmonoa, 2009). It has also been reported that within their small territories, breeding Common Cranes (*Grus grus*) in Spain will be near a water site and a crop field where the family can forage once the chicks hatch (Alonso *et al*., 2004). Territorial cranes probably benefit from lower energy expenditure by travelling shorter distances from their roost to forage site (Terrill, 1990). Therefore, Blue Crane breeding sites in this study are more likely found within these core areas where the cranes can limit their energy expenditure and even utilize those areas for years as long as resources are available.

Cranes regularly feed in agricultural lands because of the abundance of food resources provided. Agricultural transformation has increased the number of areas for food and territories in the Overberg, making the landscape more suitable for Blue Cranes. While it would be expected that agriculture has created fragmentation of the landscape and has reduced the quality of the landscape, fragmentation in the agricultural landscape won't necessarily reduce quality as it might in a natural environment. Movement studies have shown that avian home range is influenced by the quality of their habitat (Newton, 1998). For example, McCann and Benn (2006) reported that Wattled Cranes (*Bugeranus carunculatus)* in KwaZulu-Natal breeding in predominantly natural vegetation had smaller home ranges than cranes breeding in transformed habitats, suggesting that cranes increase their home range in degraded landscapes. My study may indicate that breeding Blue Cranes home ranges can be influenced by the abundance of resources provided by the agricultural lands in the Overberg. Blue Cranes in this study that did not exhibit much of a change in their home range between seasons could also indicate that their home range provides abundant resources for both the breeding and non-breeding season, so they do not need to alter their home range when breeding.

Individually, a couple of non-breeding cranes had much larger home ranges than breeding cranes, but overall the home range of most non-breeding cranes were similar in size to breeding cranes. The larger home ranges of some non-breeding cranes may reflect foraging flocks not revisiting the same feeding grounds on a daily basis. This behaviour has been reported in Common Cranes in which non-breeding flocks forage on a field until their average feeding rate decreases below a threshold, which triggers a move to another foraging site (Alonso *et al*., 2004). Alternatively, breeding cranes may displace non-breeding cranes from their territories (Bennett,

1989). Non-breeding cranes can also be influenced by foraging aggregations. Flocks of cranes moving to foraging grounds tend to join existing groups of cranes to form large foraging aggregations (Starling and Krapu, 2014; Wittenberger and Dollinger, 1984).

Unsurprisingly, my results suggest that both non-breeding and breeding Blue Cranes have a higher tolerance to disturbance of habitat than Blue Cranes in other provinces due to the abundance of resources the landscape offers to provide for their daily requirements. This finding was also seen in the Wattled Cranes in KwaZulu-Natal (McCann and Benn, 2006). The results suggest that the factors that affect the home range of Blue Cranes in the Overberg is context specific and that the agricultural landscape of the Overberg may have had more of a significant effect on their home range.

4.2. Daily Movements

As expected, breeding cranes travelled shorter daily distances than non-breeding cranes. Numerous studies show that cranes change their movements and time budget based of the availability of resources and habitat (Yang *et al*., 2007; Khan *et al*., 2014; Zhou *et al*., 2010; Starling and Kapu, 1994). More specifically, Mmonoa (2009) found that not only were nest sites of breeding Blue Cranes found in agricultural land, but were found in close proximity to a water source, suggesting that this allows non-incubating cranes to roost close to the nest and lead nestlings to water to reduce the risk of predation (Bidwell, 2004). While being the parents of unfledged chicks can be a key reason, being close to resources can also translate to shorter daily travel distances. While my study was not able to assess the distance of nest sites from forage sites and water sources, it suggests that there is a possible relationship between daily distance travelled and the proximity to key resources.

Both breeding and non-breeding cranes travelled further in the early morning and late afternoon than in the middle of the day. Cranes typically drink and preen at midday, travelling from roost to forage sites in the early morning and making their way back to the roost site late in the evening (Lovvorne and Kirkpatrick, 1982; Yang *et al*., 2007; Khan *et al*., 2014). Cranes typically spend more time foraging where food is abundant (Lee *et al*., 2007), which lines up with the optimal foraging theory that species will spend more time foraging in areas with high food abundance where search time will be low and will even remain in those areas to loaf/perform maintenance activities after foraging. I suggest that Blue Cranes operate within a

landscape of foraging sites with a high abundance of food, and it is advantageous to remain close to their feeding grounds throughout the day to feed at a slow pace to keep up their energy and be able to perform other activities intermittently.

Changes in distance travelled during the day is influenced by time-energy budgets. Animals perform a variety of activities throughout the day to survive and reproduce, with each activity requiring a disbursement of time and energy (Verner, 1965). Variations in how long a species spends on different activities can help increase their reproductive success (Goldstein, 1988). Multiple studies have shown that cranes spend most of the day feeding (Khan *et al*., 2014; Zhou *et al*., 2010; Aviles *et al*. 2003). Khan *et al*. (2014) argued that Black-necked Cranes (*Grus nigricollis)* in India spend more time feeding and resting during the pre-breeding season than when breeding, when feeding is reduced to allocate more time for breeding activities. By comparison, Yang *et al*. (2007) found that Black-necked Cranes in China spend more time moving in the breeding season than in winter, but this may result from low food abundance in the northwestern Sichuan Province, China. The breeding Blue Cranes in this study may have spent less time foraging and flying from different feeding grounds in the breeding season in order to allocate more time to other activities such as incubation and being vigilant, translating to even shorter distances being travelled throughout the day. Alonso *et al*. (2004) reported a similar trend in Common Cranes, where territorial families spent less time traveling to different feeding patches than flocking adults, less time feeding and double the time being vigilant.

4.3. Limitations

Due to the small sample size of our study compared to the population in the Western Cape, the kernel and MCP ranges and movements of marked birds in this study cannot be considered the foraging range of the entire population.

The study was perforce based on a small sample size of tagged cranes, which does not allow for inferences about the movements of Blue Cranes at a population level. Equipping cranes with tracking devices at different times over three years contributed to patchy data coverage, making it difficult to establish patterns and trends in home range size and use. Lack of GPS fixes between 18:00 and 06:00 may have underestimated home ranges and movement distances. It is difficult to give exact locations of nest sites for breeding cranes without disturbing the birds.

Confirmation of the breeding status of Blue Cranes does not go further into determining the pre-breeding, breeding and post-breeding stages.

4.4. Synthesis and Recommendations

The home range size and ranging behaviour of the Blue Cranes in this study are influenced by a number of factors other than their breeding status or physiology. In most cases, ranging behaviour was influenced by physiology, but environmental factors such as the landscape, quality of habitat and the abundance of resources could have influenced their ranging behaviour. This signifies the importance of the Blue Cranes adaptation to the agricultural transformation in the Overberg region and how changes in the landscape that take away territories and resources it provides can affect the survival of the population. Climate change can also be a concerning factor that can change the landscape, where less rainfall in the region can push farmers to change from grain farming, specifically wheat, to crops that require less water, such as soybeans, groundnuts and drybeans (Crop Estimates Committee, 2017).

This study gives an initial insight into the factors that affect Blue Crane movements in the Western Cape. This study also gives better knowledge of movements that will be informative in understanding the impact of threats to Blue Cranes, such as interactions with power lines and wind turbines. I recommend the continued tracking of cranes to determine how home ranges vary over multiple years to give greater insights on the factors underpinning their movements in the Western Cape. I also suggest observing non-breeding and breeding cranes (during both seasons) to create separate time budgets to determine how they change their daily activities and if it follows the trend of daily distance revealed in this study. These further studies should give a better idea of the amount of space the population needs and how to prepare for possible increases in development and changes in the agricultural landscape.

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Supporting Information

Table S1. Details of the 13 Blue Cranes caught the Overberg region of the Western Cape, South Africa and the tracking information used for analyses between August 2016 and January 2018.

ID	Age class	Transmission date		Number of months	Number of GPS fixes	Capture location (decimal degrees)	
		Start date	End date			Latitude	Longitude
Crane 1	Adult	07/07/2016	08/01/2018	18	3331	-34.43619	20.20578
Crane 2	Adult	07/07/2016	24/03/2017	9	1563	-34.43619	20.20578
Crane 3*	Adult	07/07/2016	26/07/2016	<1	120	-34.43619	20.20578
Crane 4	Juvenile	12/07/2016	19/12/2016	5	966	-34.31053	20.00919
Crane 5	Adult	13/07/2016	07/01/2018	6	3257	-34.31053	20.00919
Crane 6	Adult	13/07/2016	08/01/2018	6	3305	-34.31053	20.00919
Crane 7	Adult	05/08/2017	08/01/2018	5	941	-34.29993	19.89818
Crane 8	Adult	04/08/2017	08/01/2018	5	961	-34.29993	19.89818
Crane 9	Adult	05/08/2017	08/01/2018	5	942	-34.29993	19.89818
Crane 10	Adult	06/08/2017	14/11/2017	3	605	-34.43599	20.19699
Crane 11	Adult	04/08/2017	14/11/2017	3	414	-34.29993	19.89818
Crane 12	Adult	04/08/2017	08/01/2018	5	808	-34.28762	19.90115
Crane 13	Adult	04/08/2016	08/01/2018	5	885	-34.29993	19.89818
Total		-	-	**76**	**18098**	-	-

*excluded from analyses because too few tracking data were obtained

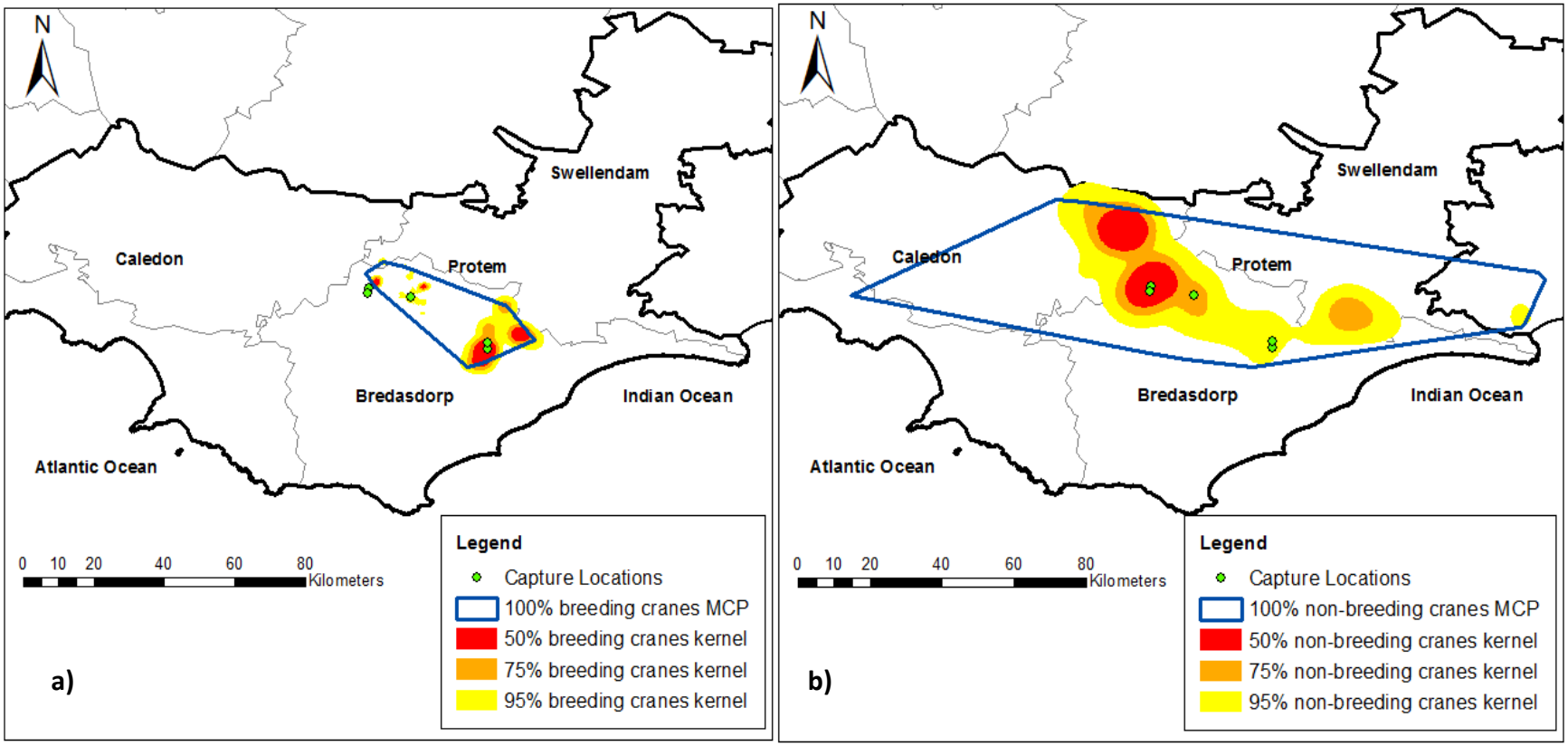

Figure S2. Blue Crane Minimum Convex Polygons (MCP) and 50%, 75% and 95% kernel home ranges in the Overberg Region of South Africa showing the total range collectively for a) breeding cranes (n=5), b) non-breeding cranes (n=7).

Figure S3. There was no relationship between 95% kernel estimates of home ranges and the number of GPS fixes for each individual (R^2=0.03416).

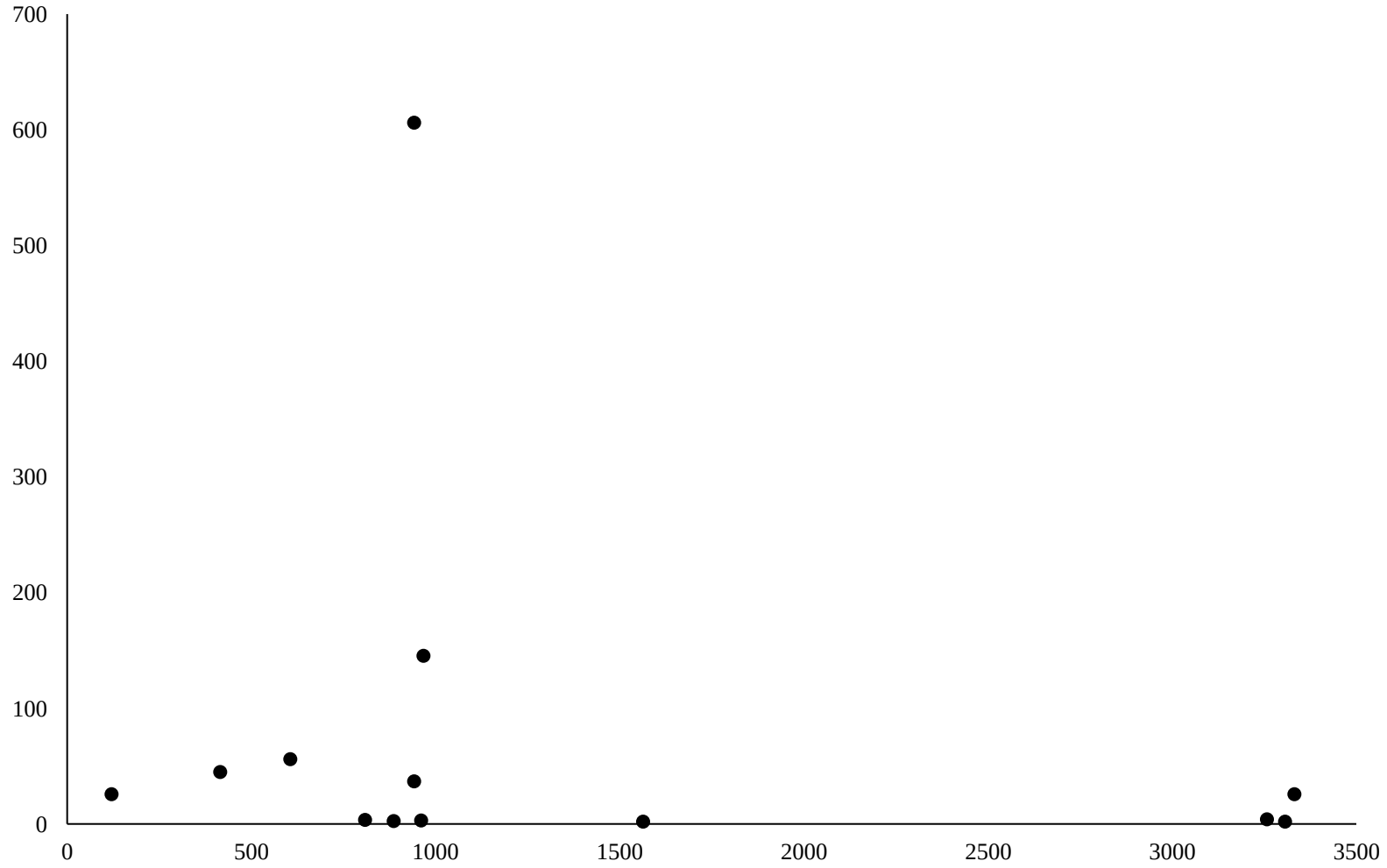

Figure S4 Comparing average daily flight distances and the number of GPS fixes for each individual. No correlation was found between home range and number of GPS fixes (R^2=0.10204).

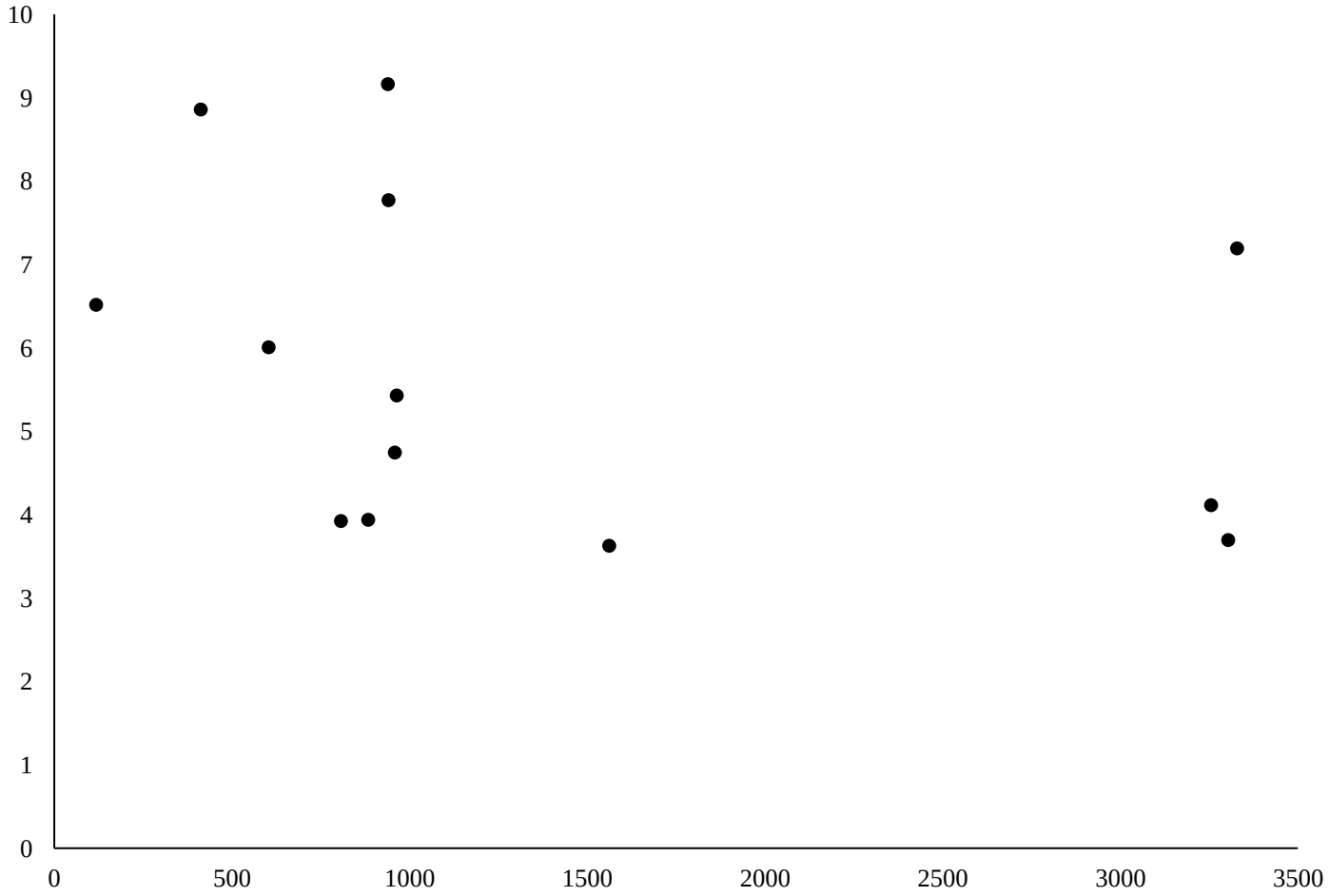

Table S5. Blue Crane ranging information showing average daily distances and kernel and MCP home range sizes in km^2 depicted by individual.

Individual	Average daily distance (mean ± SD, km)	Kernel home range (km^2)			MCP home range (km^2)
		95%	75%	50%	
Crane 1	7.2 ± 1.7	10.9	3.1	0.8	101.0
Crane 2	3.6 ± 0.7	0.8	0.3	0.2	2.5
Crane 4	5.4 ± 1.4	47.1	18.3	7.8	62.3
Crane 5	4.1 ± 1.0	2.4	0.4	0.0	23.6
Crane 6	3.7 ± 1.0	1.1	0.2	0.06	5.3
Crane 7	9.2 ± 3.5	257.3	66.0	26.4	281.1
Crane 8	4.7 ± 1.2	1.3	0.4	0.1	2.3
Crane 9	7.8 ± 2.0	14.6	4.5	1.4	31.3
Crane 10	6.0 ± 1.6	18.7	7.4	2.7	12.9
Crane 11	8.9 ± 2.1	16.1	5.5	2.3	21.5
Crane 12	3.9 ± 1.3	1.7	0.4	0.1	6.9
Crane 13	3.9 ± 1.2	1.1	0.3	0.1	1.6

Table S6. The key analyses with a description of the analytical approach used, specifying the response and explanatory terms (fixed and random terms) included in models.

Analytical approach		
I. Comparing home range sizes between individuals (General Linear Models)		
Analysis	Response term	Explanatory terms (random terms in parentheses): Distribution
1a) Influence of breeding status on total home range size breeding adults and non-breeding adults	Total 95% kernel home ranges	Status (Individual): Normal, number of days of data
1b) Influence of season on home range of breeding adults	95% kernel home ranges by season	Season, Days of data, (Individual): Normal
II. Comparing daily distances moved between individuals (General Linear Models)		
Analysis	Response term	Explanatory terms (random terms in parentheses): Distribution
2a) Influence of breeding status on average daily distances of breeding adults and non-breeding adults	Average daily distance	Status, Days of data, (Individual): Normal
2b) Influence of season on distance of breeding adults	Average daily distance by season	Season, Days of data, (Individual): Normal
III. Comparing daily distances moved between individuals (General Linear Models)		
Analysis	Response term	Explanatory terms (random terms in parentheses): Distribution
3a) Influence of breeding status on average roost to forage distances of breeding adults and non-breeding adults	Average roost to forage distance	Status, Days of data, (Individual): Normal

3b) Influence of season on roost to forage distances of breeding adults	Average roost to forage distance by season	Season, Days of data, (Individual): Normal
IV. Distances moved per time interval between individuals (General Linear Models)		
Analysis	Response term	Explanatory terms (random terms in parentheses): Distribution
4a) Influence of breeding status on distance per time interval of breeding adults and non-breeding adults	Distance/hour per time interval	Status, Days of data, (Individual): Normal
4b) Influence of time on distance per time interval of breeding adults and non-breeding adults	Distance/hour per time interval	Time, Days of data, (Individual): Normal
4c) Influence of season on distance per time interval of breeding adults	Distance/hour time interval by season	Season, Days of data, (Individual): Normal
4d) Influence of time on distance of breeding adults	Distance/hour time interval by season	Time, Days of data, (Individual): Normal