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Post-fledging movement and spatial ecology of the endangered Cape Vulture (*Gyps coprotheres*)

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Abstract

The post-fledging dependence period (PFDP) is one of the most critical stages in the life history of some avian species. Birds are particularly sensitive to mortality during this stage as they must learn essential skills, such as efficient locomotion, proficient food location and predator avoidance. Knowledge of the PFDP would provide valuable information for conservation management of endangered species, many of which experience high juvenile fatality rates. Post-fledging movements of five endangered Cape Vultures were recorded using Global Positioning System/Global System for Mobile communication telemetry in South Africa. Home range sizes, distances travelled from the nest and habitat use were determined over 11 months during the PFDP. Fledglings increased their home range progressively for the first 2 months, then exhibited a rapid increase in home range size associated with dispersal from their natal colony. Maximum net daily distance also rapidly increased following the dispersal period. A preference for protected areas and woody vegetation (representing cliff faces used for roosting) in terms of habitat use for foraging was evident. The knowledge of the movement and habitat use of juvenile Cape Vultures can aid in the effective conservation planning for the species. Conservation programs in identified areas can be focused on power line and wind-farm mitigation, areas of supplementary feeding and anti-poisoning events.

Keywords Post-fledging dependence period · Home range · Habitat use · Dispersal · Juvenile fatality

Zusammenfassung

Orstbewegungen nach dem Flüggewerden und die räumliche Ökologie des bedrohten Kapgeiers (*Gyps coprotheres*)

Die Zeit direkt nach dem Flüggewerden ist einer der kritischsten Abschnitte im Leben einer Vogelart. In dem Stadium ist die Sterblichkeitsrate der Vögel besonders hoch, da sie in dann ganz wesentliche Fähigkeiten wie z.B. die effiziente Fortbewegung, das geschickte Auffinden von Nahrung sowie das Vermeiden von Feinden erlernen müssen. Genaueres Wissen über diesen Lebensabschnitt böte dem Management für den Schutz bedrohter Arten wertvolle Informationen, da viele dieser Arten in ihrer juvenilen Lebensphase eine hohe Sterblichkeitsrate aufweisen. Für fünf gefährdete Kapgeier zeichneten wir in Südafrika nach dem Flüggewerden die Ortsbewegungen mittels GPS/GSM-Telemetrie auf. Über elf Monate hinweg wurde während dieser Lebensphase ihr Aktionsradius, die Strecken zwischen Nest und genutztem Habitat, aufgezeichnet. In den ersten beiden Monaten erweiterten die fliegenden Jungtiere kontinuierlich ihren Aktionsradius; dann vergrößerten sie ihn rapide, verbunden mit der Ausbreitung weg von ihrer Brutkolonie. Im Verlauf dieser Ausbreitung vergrößerte sich rasch auch die maximale tägliche Entfernung von der Kolonie. Bei der Nahrungssuche zeigten sie eine klare Präferenz für Naturschutzgebiete und für Gehölzvegetation (mit steilen Felswänden zum Übernachten). Genauere Informationen über die Ortsbewegungen und Habitatnutzung junger Kapgeier kann bei der Planung effektiver Schutzmaßnahmen für diese Art helfen. Programme zu ihrem Schutz können sich in ausgewiesenen Gebieten auf die Entschärfung von Hochspannungsleitungen und Windkraftanlagen konzentrieren sowie auf Gebiete für zusätzliche Fütterung und die Bekämpfung des Auslegens von Giftködern.

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Extended author information available on the last page of the article

Introduction

With an ever-increasing human population, and its associated infrastructure, anthropogenic threats are becoming a foremost concern to many wildlife species, particularly

birds (Loss et al. 2015; Pfeiffer et al. 2015a). Environmental conditions, resource availability, age, and breeding status at which a species uses its environment influence its fitness (Johnson 2007; Morrison and Wood 2009). Large raptor populations are sensitive to adult mortalities; however, high juvenile mortality rates also affect the population (Yamaç and Bilgin 2012). High mortality rates of juvenile raptors are associated with inexperience in basic fundamental tasks (adequate flight abilities; efficient resource location) and naïve individuals moving across an extensive, unfamiliar landscape (Yamaç and Bilgin 2012; Harel et al. 2016; Krüger et al. 2014). The post-fledging dependence period (PFDP), the time period between the first flight from the nest and the inception of dispersal, is one of the most critical stages in the life history of birds (López-López et al. 2014). During this time, fledged individuals must learn to become self-sufficient, gain flight skills and effectively locate food sources (Delgado et al. 2009a; López-López et al. 2014; Krüger and Amar 2017). Following the PFDP, juvenile raptor populations are often observed close to the natal area after which time they slowly start to ‘drift’ further away from the natal surrounds (López-López et al. 2014; Yamaç and Bilgin 2012; Krüger et al. 2014; Sandgren et al. 2014). It is speculated that this movement away from the natal colony may be a result of the improvement of flight abilities (Yamaç and Bilgin 2012; Krüger et al. 2014). Consequently, as flight ability improves with age, individuals are able to move longer distances, covering larger areas. Juvenile raptors often exhibit larger home ranges when compared to adults and this may be linked to the fact that juveniles are often out-competed for resources by more competent adults (Yamaç and Bilgin 2012; Krüger et al. 2014). Secondly, juvenile birds are not philopatric and therefore do not have to return to the colony for breeding (Yamaç and Bilgin 2012; Krüger et al. 2014). During this dispersal phase when juveniles move across extensive, unfamiliar environments mortality rates are high given their inexperience of flight in unfamiliar terrain (Harel et al. 2016; Yamaç and Bilgin 2012).

Juveniles during their early life stages are said to suffer higher mortality rates than adults (Péron and Grémillet 2013), with mortality rates peaking during the first several months and, of the birds that fledge, nearly half are said to die within the first year (Wiens et al. 2006). Low survival rates of juveniles during the fledging period have been found in several studies, including those on Burrowing Owls (*Athene cunicularia*) in Alberta (45% survival rate) and Saskatchewan (48% survival) (Todd et al. 2003); Prairie falcon (*Falco mexicanus*) fledging survivorship is lower than during the egg and nestling period (McFadzen and Marzluff 1996); and Oriental White-backed Vultures (*Gyps bengalensis*) fledging mortality exceeds that of adults and subadults (Gilbert et al. 2002). High fledging mortality for *Gyps* species is not uncommon, with Cape Vultures (*Gyps*

coprotheres) estimated to have a survival rate of 17% during the first year, and only a 10.6% chance of reaching their third year (Piper et al. 1981). *Gyps* species and other Old World vultures are sensitive to higher mortality rates given their delayed maturity and low productivity (Ogada et al. 2012) and declines of vulture species may lead to breakdowns of vital ecosystem services and processes (Loss et al. 2015).

The Cape Vulture is a long-lived, obligate scavenger endemic to southern Africa (Mundy et al. 1992), currently listed on the International Union for Conservation of Nature’s Red List as ‘Endangered’ (BirdLife International 2015). It has undergone a rapid decline of 66–81% over the past 50 years, and continues to drop in range size and numbers. The 2013 global population was estimated at approximately 4700 pairs (9400 mature individuals), of which Lesotho, Eastern Cape and KwaZulu-Natal Provinces (and marginal areas of the Free State and Swaziland) contain 42% of the breeding pairs (Allan 2015). Age influences foraging range and use of the environment in terms of spatial and temporal use (Piper et al. 1989). Mature birds are often tied to colonies and forage within a certain range around the colony, returning to the colony every night, and are thus considered central place foragers (Boshoff and Minnie 2011; Pfeiffer et al. 2015b). Foraging ranges are influenced by surrounding land use practices, and sparse and ephemerally distributed food sources (Phipps et al. 2013; Pfeiffer et al. 2015b; Kane et al. 2016). Colonies are often located in protected areas and use of such areas by adult birds is often highest during the breeding season, whilst farming area use (communal and private farmland) is prevalent during the non-breeding season (Pfeiffer et al. 2015b; Phipps et al. 2013). Breeding birds are spatially constricted in their foraging movement (40–60 km radius from the colony), so as to encounter potential opportunities for breeding and care of nestlings (Boshoff et al. 2010; Pfeiffer et al. 2015b; Phipps et al. 2013). Juveniles are restricted to the colony for the first few months, as a result of being exclusively or partially dependent on their parents for food, until the following breeding season starts, when parents stop providing food, and they disperse from the colony and travel throughout the subcontinent (Piper et al. 1981). Immature Cape Vultures have been shown to have far greater home ranges than adult Cape Vultures (Kane et al. 2016; Phipps et al. 2013).

Inexperienced flight combined with the lack of knowledge of the surrounding areas in fledged vulture individuals may expose them to a greater assortment of threats across an extensive landscape during their first years of exploration (Krüger et al. 2014; Harel et al. 2016; Krüger and Amar 2017). Detailed knowledge of juvenile PFDP may provide valuable information on the risks that fledglings face, and this is particularly important in the case of endangered species, which often face stochastic events during their exploratory PFDP (Delgado et al. 2009b). Thus, understanding how

Cape Vultures use their environment during the PFDP and knowledge of the timing of dispersal can provide crucial information for conservation management of this long-lived, late-maturing endangered species.

The aim of the study was to determine the post-fledging movements and spatial ecology of juvenile Cape Vultures in South Africa. Home range of fledged individuals, time of natal dispersal, maximum net daily distance travelled, as well as habitat use of juveniles was determined. It was predicted that home range of fledged individuals would increase with age, natal dispersal would coincide with the subsequent breeding season for adult birds and habitat use would be similar to that of adults.

Methods

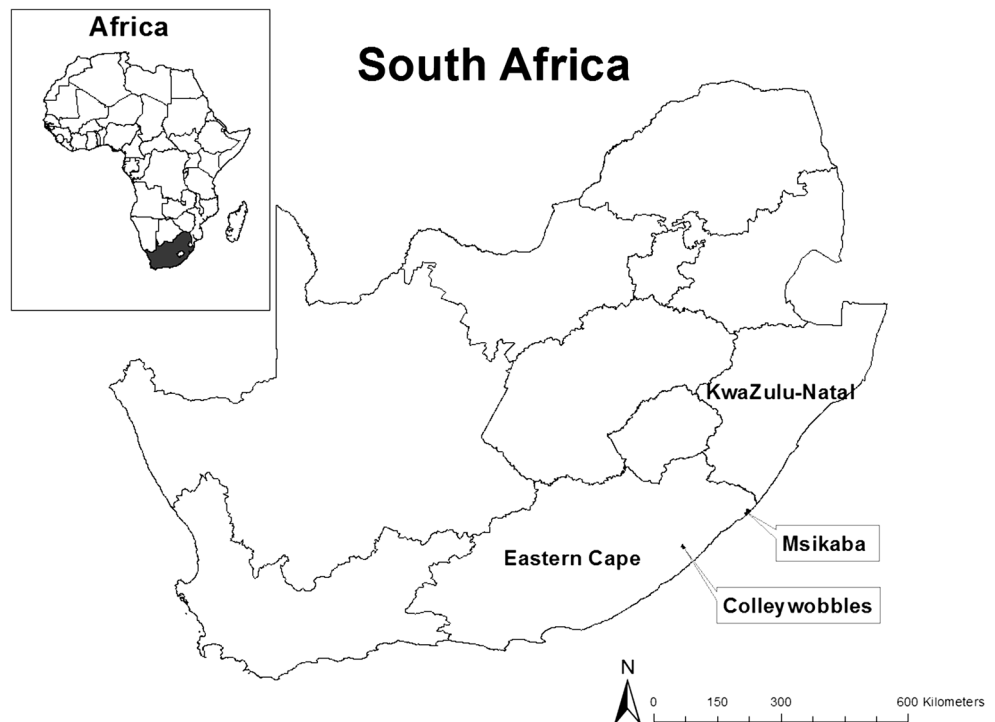
Study site

Colleywobbles Vulture Colony (32°0'S, 28°35'E; Fig. 1) is situated along cliffs above the Mbashe River in the Idutywa District of the former Transkei, Eastern Cape Province, South Africa. It is an ancestral vulture colony, being in existence since at least the 1890s (BirdLife South Africa 2015). It is the largest colony in the Southern Node (which constitute the Eastern Cape and KwaZulu-Natal Provinces of South Africa together with Lesotho), supporting more than 4% (on average 200 breeding pairs) of the global population of Cape Vulture and is a 3100-ha globally important bird

area (Important Bird and Biodiversity Area number SA088) (BirdLife South Africa 2015). The former Transkei, with its abundance of carrion as a result of higher livestock mortality rates, attributed to communal subsistence farming, provides an abundant food source (Vernon 1998; Pfeiffer et al. 2015a,b). Furthermore, competition from large predators may be insignificant as only two meso-carnivores persist in the area (Black-backed Jackal (*Canis mesomelas*) and Caracal (*Caracal caracal*)) (Brown and Piper 1988).

Eight nestlings from Colleywobbles Vulture Colony were fitted with Global Positioning System (GPS)/Global System for Mobile communication transmitters (Cellular Tracking Technologies, Rio Grande, NJ) in September 2015. Temporary extraction of nestlings from their nests was carried out by placing them in a secure bag and hoisting them to the top of the cliff. Each nestling was fitted with a transmitter (weighing on average 136 g) attached as a pelvic mount, a metal SAFRING ring and a yellow patagial tag. Transmitters were set to record from sunrise to sunset at 15-min intervals. GPS locations of vultures, horizontal dilution of precision, fix quality, direction of travel, speed and altitude were recorded. Data were uploaded to the manufacturer's website when the unit had cellular coverage during the transmission time (Greenwich Mean Time + 2). Of the eight transmitters deployed, only five recorded data once fitted to the birds. It is unknown why the transmitters failed, but a complete battery drain due to the nestlings remaining multiple months in the shade (batteries were charged with solar power) before fledging could have contributed to this problem. Of the three

Fig. 1 Location of the Colleywobbles and Msikaba Cape Vulture Colony in the Eastern Cape Province, South Africa



transmitters that did not transmit data, one bird was found dead below a power line (Ndalo; ring number G26716, wing tag X050), which confirmed the bird's dispersal, but GPS movements were not recorded. Mkhalolo (ring number G26707, wing tag X057), a second bird that did not transmit data, was spotted by a member of the public in December 2016, confirming the bird's dispersal (Pfeiffer et al. 2017). Of the remaining five functioning transmitters, two ceased transmitting after 11 months as the birds were found dead at the base of power lines.

Transmitter data were collected for 11 months post-fledging between November 2015 and November 2016 (a combined total of 55 bird-months; Table 1; 19,773 (mean = 3955, SD = 683) GPS fixes in total; Table 2).

Home range size

GPS data were downloaded as a spreadsheet from the manufacturer's website and filtered for technical errors. GPS locations located in inaccurate Universal Transverse Mercator zones that had a poor quality fix (type of fix < 3) were removed. Duplicate date and time stamps were also removed. Home range of each individual was determined by means of a fixed kernel density estimate (KDE) with a reference bandwidth (HRef) in the reproducible home range package (Signer and Balkenhol 2015) in R (Laver and Kelly 2008; R Core Team 2016). To eliminate potential bias in the approximation of space use as a result of individual

variability, a random sample from the data set was selected and a Spearman's rank test was conducted to determine the correlation between the number of location fixes used for the KDE and the size of the home range.

The fixed 50% KDE and 99% KDE were calculated over each 14-day period. The 14-day period was considered the maximum time a fledgling could survive without aid from its parents (Mundy et al. 1992). Fifty percent KDE represented core areas utilised, whilst 99% KDE represented home range. Although home range is often determined at 95% KDE, this generally produced fragmented and under-smoothed contours, and thus 99% KDE was selected (Phipps et al. 2013; Pfeiffer et al. 2015b). Changes in fledging home range size in each 14-day period over 11 months (315 days) was explored using a general linear model, with Period as a continuous variable and Individual as a fixed effect. Statistical analyses were conducted in SPSS (IBM Corp 2016). The mean core area and home range of juvenile birds during the PFDP (this is prior to dispersal-see below) was also calculated.

Dispersal distance

To determine the range of Cape Vulture fledging movements each individual's maximum net daily distance from the nest was calculated. Maximum net daily distance from the nest to the furthest location for that day was calculated based on the straight-line distance (Signer and Balkenhol 2015). The

Table 1 Tracking details between September 2015 and November 2016 for five fledging Cape Vultures. Tracking of Lunguza and Sibane terminated when the birds were found dead below power lines

Identifier (ID)	Date tagged	Date fledged	Date tracking terminated	Dispersal date	Post-fledging dependence period (days)	Months tracked
Lunguza (X052)	23 September 2015	11 December 2015	09 November 2016	07 April 2016	118	11
Mbashe (X071)	23 September 2015	16 December 2015	02 November 2016	20 February 2016	66	11
Msikiti (X053)	23 September 2015	31 December 2015	19 November 2016	02 May 2016	123	11
Sibane (X056)	24 September 2015	12 December 2015	06 November 2016	23 Apr 2016	133	11
Xobo (X055)	23 September 2015	21 December 2015	11 November 2016	23 Feb 2016	64	11

Table 2 Total number of Global Positioning System (GPS) fixes, average number of GPS fixes per day, home range sizes of 50% kernel density estimate (50% KDE), 99% KDE and the maximum net daily distance travelled from the nest by five fledging Cape Vultures 11 months post-fledging

ID	No. of GPS fixes	No. of GPS fixes per day	Home range (km ²)		Maximum net daily distance (km)
			50% KDE	99% KDE	
Lunguza (X052)	3076	137	1005.81	6095.03	183
Mbashe (X071)	4007	180	5326.03	29080.57	227
Msikiti (X053)	4167	188	4522.43	23955.98	306
Sibane (X056)	4918	221	2846.75	18976.32	192
Xobo (X055)	3605	161	8689.52	48407.46	469
Mean	3955±	177	4478.11 ±	25303.07 ±	275
±SD	683	31	2879.89	15482.84	96.86

first day an individual flew over 100 m was considered the date of fledging, commencing the PFDP.

Dispersal date from the nest was calculated using the fledgling's maximum net daily distance. The methods described in Weston et al. (2013) and Krüger and Amar (2017) were used to identify when the birds became independent of their natal colony. Five adult Cape Vultures home ranges were used as representative of possible parental influence. Adult bird data were from the Msikaba Cape Vulture colony (31°16'S, 29°59'E; Fig. 1) in the Mkambati Nature Reserve during the breeding season (Pfeiffer et al. 2015b). The Msikaba colony is located approximately 150 km from Colleywobles. Although the data were not from the same colonies, given the colonies' proximity and their location in the former Transkei, similar results were expected.

The radii of the mean 99% KDE (93 km) and the mean 50% KDE (46 km) were taken as areas of potential parent influence. A 14-day period away from the natal home range was used as representative of independence. An individual was considered dispersed when it moved away from the adults' mean maximum ranging area (93 km) and did not return to the adults' mean core area (46 km) for the following 14 days (Pfeiffer et al. 2015b). Changes in distance over time were explored using a general linear model, with Day as a continuous variable and Individual as a fixed effect. To determine the relationship between Day and distance from the natal colony, four regression models (linear, quadratic, inverse, logarithmic) were fitted to the data to demonstrate the best fit. Statistical analyses were conducted in SPSS (IBM 2016).

Habitat use

Using the South African National Land Cover Database (South African National Biodiversity Institute 2014) amalgamated with the protected areas of South Africa and Lesotho (International Union for Conservation of Nature and United Nations Environmental Programmes World Conservation Monitoring Centre 2016), a land use map was created. Six land use classes were reclassified from the original 71 land use categories, namely commercial farmland, subsistence farmland, natural woody vegetation, tree plantations, urban centres and village communities, as per the method adapted from Pfeiffer et al. (2015b).

The pooled locations of fledgling's 99% KDEs were clipped to the final reclassified land use map, excluding areas that extended beyond South African borders (Botswana, Lesotho), given limited vegetation maps. Within the 99% KDE, areas of all land uses were calculated (squared kilometres). GPS locations were considered the observed number of positions per habitat. Assuming individuals show no habitat preference, the expected number of GPS locations per habitat should be proportional to the amount of habitat within the

99% KDE. Therefore, considering each land use separately, habitat use in proportion to habitat availability was tested with the χ^2 -test. Bonferroni confidence intervals, calculated in Microsoft Excel, were used to determine habitat use in proportion to habitat availability (Byers et al. 1984).

Results

Home range

The size of the 50% KDE [$r_s(60)=0.173$, $P > 0.05$] was not correlated to the number of fixes, whilst the size of the 99% KDE [$r_s(60)=0.350$, $p < 0.05$] was correlated to number of fixes. Home range size of the five individuals did not differ significantly at the 50% KDE ($F=3.73$, $df=4$, $p > 0.05$), but differed at the 99% KDE ($F=4.61$, $df=4$, $p < 0.05$). A post hoc Tukey honest significant difference test showed that at the 99% KDE, the individuals Lunguza and Xobo differed significantly at $p < 0.5$. Home range size between 14-day periods did differ significantly at the 50% KDE ($F=16.06$, $df=1$, $p < 0.001$) and the 99% KDE ($F=13.16$, $df=1$, $p < 0.001$) as illustrated in Fig. 2. Cumulative home range size increased from a mean of 180 km² (SD=201.676 km²) and 2 228 km² (SD=2 558.786 km²) in the first 14 days to a mean cumulative home range of 36 444 km² (SD=27 168.59 km²) and 287 199 km² (222,546.50 km²) at 11 months for the 50 and 99% KDEs (Fig. 3). During the PFDP the mean 50% KDE and 99% KDE were calculated as 986 and 14,363 km², which translates to a core radius of 18 km and a home range radius of 68 km, respectively.

Dispersal

The maximum net daily distance of each individual from the natal colony increased significantly ($F=200.11$, $p < 0.001$) over time. There was a noticeable increase in maximum net daily distance around 100 days (during April). Of the four regression models fitted to the data of the maximum daily distance from the colony of each individual, the R^2 quadratic regression was the best fit (Fig. 4). Fig. A1 illustrates dispersal movement once individuals were independent from parental influence.

Habitat use

Observed habitat use was not selected in proportion to expected habitat availability when the pooled 99% KDE locations were used. Fledged Cape Vultures showed a preference for protected areas and woody vegetation (Table 3). Villages, urban areas, plantations, commercial farmland and subsistence farmland did not appear to be favourable habitat for juvenile Cape Vultures.

Fig. 2 Mean size of the 50% kernel density estimate (50%KDE) and 99% kernel density estimate (99%KDE) home range (km²) of five fledged Cape Vultures illustrated in 14-day intervals for the first 11 months

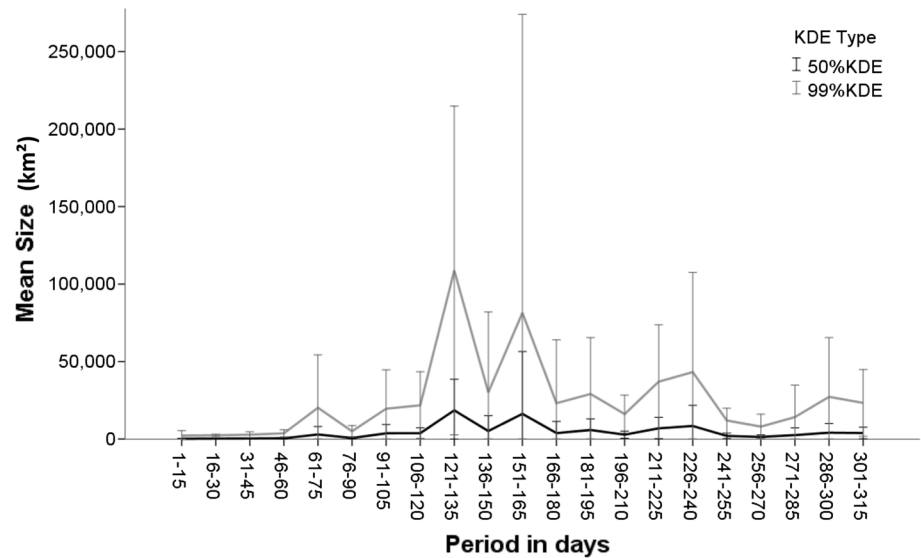
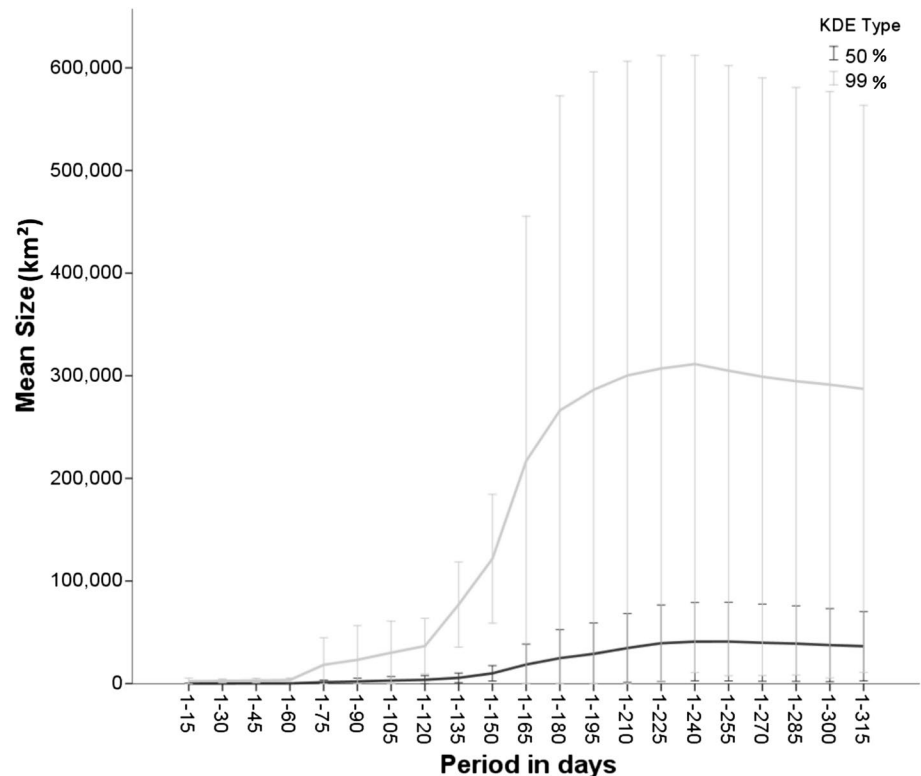


Fig. 3 Mean size of the 50% KDE and 99% KDE cumulative home range (km²) of five fledged Cape Vultures for the first 11 months



Discussion

Detailed spatial movements of recently fledged Cape Vultures and their habitat use are provided in our study, which can aid in the conservation management of this species. Although the sample size is relatively small, it provides explicit information on the home range, PFDP, the onset of natal dispersal and the habitat use of these juvenile Cape

Vultures using accurate technological advances. Furthermore, it highlights the individual variation in movement and spatial use.

Home range sizes of newly fledged Cape Vulture individuals did not differ at the 50% KDE but did differ at the 99% KDE. This difference may be attributed to a single bird's flight up to Botswana, increasing the mean size of the 99% KDE. Home range size increased progressively during the first 60 days, with a sudden increase of home range

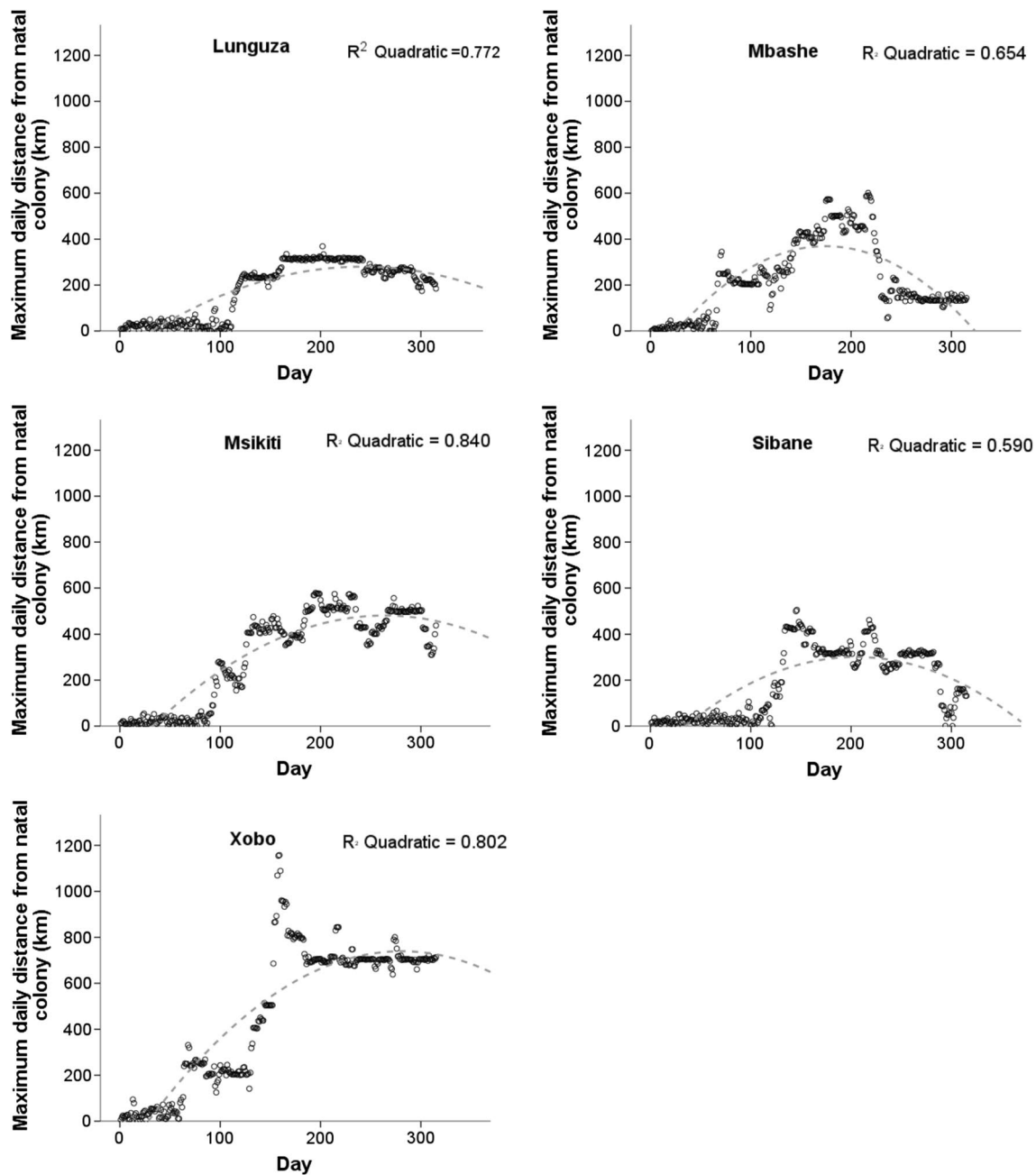


Fig. 4 Mean maximum net daily distance (km) from the nest of five fledging Cape Vultures for 11 months with a quadratic curve fitted

size at 120 days. The areas traversed in this study by Cape Vulture fledglings are in the range of areas found in other studies of immature and first-year Cape Vultures (Phipps et al. 2013; Kane et al. 2016), whilst fledging Cape Vultures displayed larger areas than breeding and non-breeding adult birds (Pfeiffer et al. 2015b). Fledging Cape Vultures displayed a similar trend to Cinereous Vultures (*Aegypius monachus*) from Turkey, where the first 2 months were spent in close proximity to the natal area, after which time a gradual increase in home range size was observed as individuals

moved further away (Yamaç and Bilgin 2012). The increase in home range size may be due to a number of reasons. Firstly, as individuals age, they may explore the surrounding territory, resulting in progressively larger home ranges. This has been observed in Bearded Vultures (*Gypaetus barbatus*) in the Maloti-Drakensberg, South Africa where home range size increased as individuals aged (Krüger et al. 2014). Secondly, juveniles may be outcompeted by more experienced adult birds for food sources around the colony, and consequently have to move further afield, resulting in larger

Table 3 Pooled 99% KDE habitat availability of fledged Cape Vultures based on the South African reclassified land use map

Habitat type	Contribution (%)	Area (km ²)	Pi	Pio	Bonferroni CI	Conclusion
Protected area	17	28374.00	0.301	0.174	0.281 < <i>P</i> < 0.321	Preferred
Village	10	16823.29	0.012	0.103	0.008 < <i>P</i> < 0.017	Not preferred
Urban	7	11491.08	0.002	0.071	0.000 < <i>P</i> < 0.005	Not preferred
Plantation	8	13207.12	0.007	0.081	0.003 < <i>P</i> < 0.011	Not preferred
Woody vegetation	5	8031.78	0.502	0.049	0.480 < <i>P</i> < 0.523	Preferred
Commercial farmland	35	57085.08	0.136	0.350	0.121 < <i>P</i> < 0.151	Not preferred
Subsistence farmland	17	27922.59	0.040	0.171	0.031 < <i>P</i> < 0.049	Not preferred

Bonferroni confidence intervals were used to determine Cape Vulture habitat use in 99% pooled KDE; Juvenile = 3778; *Z*, 2.69

Pi Actual proportion of usage, *Pio* expected proportion of usage, *CI* confidence intervals

home ranges (Mundy et al. 1992). Additionally, the increase of home range size around 120 days of fledging of Cape Vultures coincides with the subsequent breeding season of adult birds, during which time parental care and food provision to fledglings decreases, and as such the juveniles may have to move across the wider landscape (Mundy et al. 1992). The extensive range covered by fledging Cape Vultures provides evidence that fledged individuals wander far and wide in the landscape, as has been previously suggested (Piper 1994).

Fledgling birds experienced a mean PFDP of 101 days, and the distance from the nest increased after this period, as fledglings may no longer be dependent on their parents. The mean of the PFDP is similar to that of a Cape Vulture study from the Potberg Colony, Western Cape, South Africa (Robertson 1985) and Bearded Vultures of the Maloti-Drakensberg region of South Africa and Lesotho (Krüger and Amar 2017). Longer parental care of Old World vultures is expected given their body size, development of flight abilities and dependence on unpredictable food sources (Donázár and Ceballos 1990).

The mean maximum net daily distance from the natal colony remained relatively close to the colony in the first 100 days (Fig. 4), and this coincided with the PFDP experienced by the fledglings. Mean core area (50% KDE) and mean home range (99% KDE) size during the PFDP were 986 and 14,363 km², which translates to a core radius and home range radius of 18 and 68 km, respectively. Dispersal from the nest was apparent from 100 days onwards. This dispersal period of 100 days (\pm 3 months) is slightly longer than that observed in Bearded Vultures from northern Spain (López-López et al. 2014) and Cinereous Vultures in Turkey (Yamaç and Bilgin 2012), which dispersed from the natal area within 2 months. It is evident that Cape Vulture fledglings remained in locations of similar distance from the colony for extended periods (as indicated by the points forming a straight horizontal line in Fig. 4). It is a possibility that areas where fledglings remained are nursery areas

(Mundy et al. 1992). Nursery areas are often established away from breeding colonies so as to minimise competition for scarce food resources with more competent adults, and have been observed in other species (Negro et al. 1997; Dwyer et al. 2010). It is therefore possible that fledglings move away from the colony, stay away from the colony for approximately 3 months, after which some individuals start returning to the natal colony (Fig. 4). This is in contrast to Piper et al. (1981) who stated that the Cape Vulture returns to the colony and potentially starts breeding at 4–5 years.

Large ranging behaviours in fledged vultures have previously been speculated to be related to scarce food sources in the landscape and to avoid competition with more competent adults (Phipps et al. 2013). In terms of habitat use by fledged Cape Vultures, preference was given to protected areas and woody vegetation. The use of protected areas by fledglings may be linked to vultures' social foraging behaviour. Protected areas often contain adult vulture breeding colonies and feeding sites, and it is assumed that young birds use adults for learning, and thus follow adults to colonies and feeding sites. Protected areas predominately used by Cape Vultures (Table A1) in our study cover an extensive area of South Africa and cross a number of provincial borders, highlighting the need for provincial conservation agencies to collaborate to ensure similar management objectives are ascertained for this endangered species. The use of woody vegetation may be misrepresented, as suggested by Pfeiffer et al. (2015b). Cliffs located above woody vegetation may have been used as roosting sites, yet may have been misrepresented as woody vegetation based on the forested areas generally located below cliffs. It is interesting to note that areas of subsistence farmland were not preferred, as was speculated. Adult birds used subsistence farmland during both the breeding and non-breeding season (Pfeiffer et al. 2015b), which differs to fledglings, which showed no preference for subsistence farmland. This may support the theory that young birds are inexperienced feeders and are pushed

out (through competitive interactions for food sources) to marginal forage areas, e.g. commercial farmland, as has been observed in Bearded Vultures (Krüger et al. 2014).

It is evident that fledged Cape Vultures range over a vast area and this is a challenge in terms of conservation management. The use of protected areas by fledged Cape Vultures bodes well for management, and further conservation effort can be focused on protected areas well utilised by these young birds. The mean radius of the core area of fledglings during their PFDP falls within the recommended conservation buffer zones (35 km for roosts, 40 km for breeding colonies, 55 km for feeding sites) (Pfeiffer et al., in review) surrounding breeding colonies, thus highlights the significance of these buffers not only protecting breeding birds, but also young, inexperienced vultures. Further research may be warranted to identify nursery areas and identify management strategies for these areas. Although the study period was limited in days, it illustrated that fledglings move away from the colony, remain away for a number of months and may eventually return to the natal colony. Whether fledglings will remain in their natal colony or move away from it again requires further research.

With fledged Cape Vultures ranging over a far wider landscape, they face a variety of threats due to their inexperience when compared to adult birds. With a loss of three of eight fledgling birds fitted with trackers as a result of power lines, it is important to identify the movement and habitat use of fledglings to create an effective tool for conservation planning. By identifying such parameters, conservation efforts can focus on power line mitigation, anti-poisoning events, locations of suitable feeding sites and areas of potentially high wind energy development (which is an emerging threat to these endangered birds), such as the Eastern Cape Province, South Africa.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.


Ethical approval All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. The procedures were approved by the University of KwaZulu-Natal Ethics Committee. Permits for the capture and handling of vultures and the fitting of tracking devices were granted by the Department of Environmental Affairs through the Threatened or Protected Species permit (permit number:29551).

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