Foraging Ranges of Immature African White-Back *africanus*) and Their Use of Protected Areas in Sou

W. Louis Phipps, Stephen G. Willis , Kerri Wolter, Vinny Naidoo

Abstract

Vultures in the *Gyps* genus are declining globally. Multiple threats related to human activity have caused wic especially outside protected areas. Addressing such threats requires the estimation of foraging ranges yet s declining) species such as the African white-backed vulture (*Gyps africanus*). We tracked six immature Afric units to study their movement patterns, their use of protected areas and the time they spent in the vicinity of widely; their combined foraging ranges extended into six countries in southern Africa (mean (± SE) minimun of the vultures travelled more than 900 km from the capture site. All six vultures spent the majority of their tr protected areas were very rarely visited whereas protected areas in northern Botswana and Zimbabwe were supplementary feeding sites regularly, with consequent reduced ranging behaviour, suggesting that individu sites. We show that immature African white-backed vultures are capable of travelling throughout southern A making them susceptible to the full range of threats in the region. The standard approach of designating pro protection of such wide-ranging species against threats in the wider landscape.

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Introduction

Vultures in the *Gyps* genus are obligate scavengers and are the main consumers of ungulate carcasses in A flight, keen eyesight and social foraging behaviour enable them to locate sparsely and unpredictably distribu mammalian competitors [3], [4]. Their dependence upon such a transient and seasonally variable food supp gatherings of feeding vultures as they attempt to secure a meal whenever an opportunity arises [4]. The abi tissues of dead ungulates provides important ecosystem services by recycling carcasses, keeping energy fl spread of disease [5].

All eight *Gyps* vulture species found globally are currently declining due to multiple threats including habitat emerging threats such as climate change and fatal collisions with wind turbines and electricity cables [6]–[8] *africanus*) generally breed after their fourth year [4]) and relatively low reproductive rates make vulture popu Since the 1990s three species of *Gyps* vultures have declined by more than 95% in parts of Asia mainly due domestic livestock previously treated with the veterinary non-steroidal anti-inflammatory drug (NSAID), diclo populations has resulted in changes to scavenger community composition and a consequent increase in the humans [7]. African *Gyps* vultures are equally sensitive to the toxic effects of diclofenac and other NSAIDs, the future [11], [12].

Large declines in vulture populations have been documented in many parts of Africa, especially outside pro African vultures are food shortages caused by improved animal husbandry and over-harvesting of wild ungu they consume carcasses laced with poisons intended to kill predators of livestock [4], [13]. For example, inc cause of a 52% decline in *Gyps* vulture numbers in the Masai Mara ecosystem in Kenya over a 30 year peri forage over large areas make *Gyps* vultures particularly susceptible to mass poisoning events which tend to

Additional threats to vultures in Africa include fatal collisions and electrocutions with power lines, illegal harv or loss of breeding sites, all of which are more prevalent in unprotected areas [7], [16]. Consequently, sever increasingly restricted to protected areas in different regions of Africa and the importance of protecting them paramount to their future conservation [7], [13]–[15]. In an effort to provide an uncontaminated source of su "vulture restaurants" have been used in southern Africa since the latter half of the twentieth century [17]. Alt with supplementary feeding schemes [17], the impact of supplementary feeding on vulture foraging ecology

The African white-backed vulture is widespread in sub-Saharan Africa and is often the most numerous vultu savannah where it nests in trees in loose colonies [4]. They forage in groups and form extensive social fora air currents which they rely upon to become airborne and gain altitude due to their large body size [2], [3]. G carcass are typical and give rise to voracious feeding activity, with an individual vulture able to fill its crop wi population has been estimated at 270,000 individuals the species has suffered significant declines througho conservation status from Near Threatened to Endangered on the IUCN Red List [16]. Through re-sightings o white-backed vultures are known to travel extensively [19], but a greater understanding of their movement p required to assess their susceptibility to different threats [13].

In this study we use GPS telemetry to study the movement patterns of six immature African white-backed vu widely applied range estimation methods to determine the size, extent and seasonal variation of the vultures protected areas and supplementary feeding sites. Although the survival of breeding adult vultures is essenti tracking immature birds as we expected them to range further and consequently be most exposed to multipl their life [4], [17], [20]. As immature birds can comprise >50% of the population of African white-backed vultu on the total population size, even if adults, and therefore productivity, are relatively unaffected in the short te due to human-induced versus natural mortality is poorly understood. This study therefore provides a first ins southern Africa based on continuous GPS tracking data for the first time.

Methods

Vulture captures

Vultures were caught at a supplementary feeding site for mammalian and avian scavengers at Mankwe Wil east of Pilanesberg National Park (25°14′S, 27°05′E) in the North West Province of South Africa (Fig. 1). A v steel frame overlaid with wire mesh and baited with domestic livestock or wild ungulate carcasses was used backed vultures were caught and fitted with GPS-GSM tracking units during three separate captures.

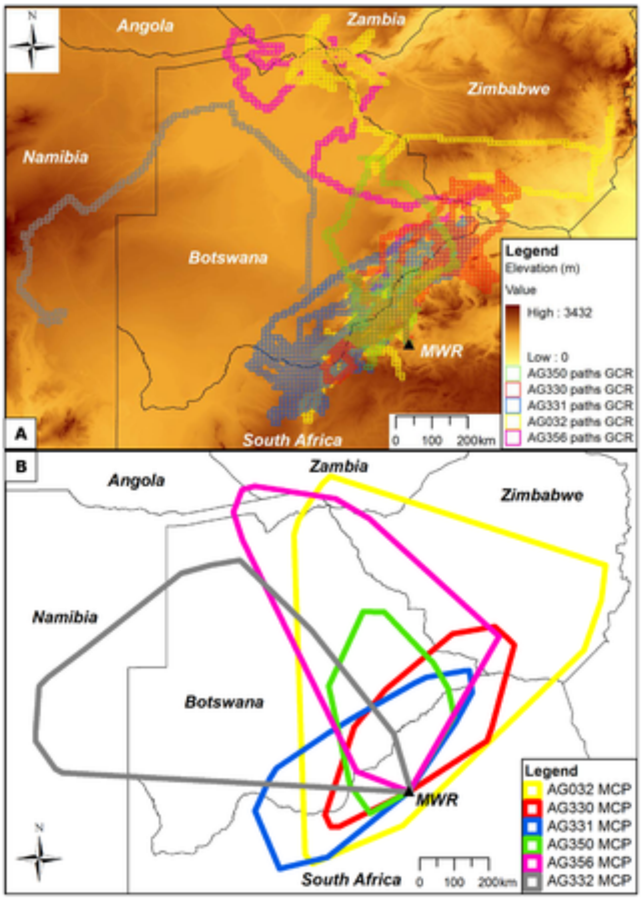

Figure 1. Foraging ranges represented by (A) path GCRs and (B) MCPs for six immature African w
Path GCRs (A) represent 10×10 km grid cells intersected by a continuous line between all consecutive G of each vulture. MCPs (B) were created by connecting the outermost GPS locations recorded for each v indicated by a black triangle and "MWR".
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GPS-GSM tracking units

Hawk105 GPS-GSM tracking units (Africa Wildlife Tracking Ltd., Pretoria, South Africa; www.awt.co.za) wer ribbon backpack-style harness enclosed in flexible plastic tubing to prevent skin abrasions [23]. Each unit w white-backed vulture [4]) and was encased in hardened epoxy resin for protection and waterproofing. The u altitude above sea level, speed and direction of travel, date, time and temperature at three times per day: 07 positional dilution of precision (PDOP) value as a measure of the accuracy of each GPS location [24]. The d database via the GSM network. Whenever a vulture was in an area without GSM coverage, up to 20,000 da transmitted when it returned to an area with coverage. It was anticipated that each unit would record and tra inscribed with a unique four character code were also attached through the patagia of both wings of each ca after release.

The procedures were approved by the Animal Use and Care Committee of the University of Pretoria (Protoc vultures and the fitting of tracking units were granted by the Department of Agriculture, Conservation, Enviro Government, Republic of South Africa (Permit: 000085 NW-09).

Data analysis

For all spatial analyses the GPS locations were projected to the UTM coordinate system (WGS 1984 UTM Z individual's GPS locations was assessed using Schoener's [25] index of autocorrelation in Home Range Too

Distances between consecutive GPS locations were calculated for each vulture. A very conservative estima was obtained by summing the distances between all GPS locations recorded in a 24 hour period (i.e. (07:00 vulture, the total distance travelled, the mean distance between consecutive locations, and the mean and m

Estimates of the foraging ranges traversed by each vulture during their total tracking periods were calculate among techniques [27]. Firstly, foraging ranges were delineated with Minimum Convex Polygons (MCPs) us tendency to overestimate the actual area occupied by an animal by including outlying locations [28], they we tracking studies on *Gyps* vultures (e.g. [20]). Incremental area analysis was carried out in Ranges7 [29] to ir represented by MCPs reached an asymptote during the total tracking period [28]. For each individual, MCPs until all locations were used to produce the MCP for the total tracking period. A foraging range area curve w [28].

Secondly, fixed kernel density estimation (KDE) was used to delineate 95% and 50% contours to represent *ad hoc* bandwidth ($h_{ad\ hoc}$) designed to reduce over-smoothing of the KDE contours [27] was used for KDE reducing the reference bandwidth (h_{ref}) in increments of 0.05 until the 95% contour became contiguous with etc.; [40], [41]). A 1000×1000 m raster cell size was used for KDE calculations. The Home Range Tools exte analysis.

Thirdly, grid cell range (GCR) estimates [28] were calculated using Hawth's Analysis Tools v3.27 [31]. A 10× connecting all consecutive locations for each individual, which represented the shortest assumed path trave the grid cells that were intersected by the path linking the consecutive locations provided an estimate of the [32]. The number of GPS locations in each grid cell was counted and core areas (core GCRs) were identifie than the mean number per cell across the overall range [33]. Path GCR estimates were also calculated for s of days) for each vulture in order to identify any seasonal patterns in ranging behaviour.

Vulture utilisation of officially protected areas was investigated separately for each vulture at the foraging ra shapefile of protected areas in southern Africa was created using data from the 2010 World Database on Pr protected areas [35] and 'national other areas' (i.e. protected areas uncategorized by IUCN) polygons from single polygon shapefile. All areas outside the protected areas polygons were designated as unprotected ar

Ivlev's electivity index [37] was used to evaluate whether protected areas were used by each vulture in prop A_i)/(U_i + A_i), where E_i is the electivity index value, and U_i and A_i are the use and availability of protected are contour occupied by protected areas defined their availability to each vulture. Use of protected areas was de locations that were recorded inside protected areas within the 95% KDE contour. We also calculated the pro protected areas to estimate their use at the core foraging range scale. Ivlev's electivity index ranges from −1 with zero indicating that use of protected areas was proportional to their availability, while positive and nega than expected, respectively.

To estimate use of supplementary feeding sites, the proportion of stationary GPS locations recorded within in southern Africa was calculated separately for each vulture. The supplementary feeding sites were identifi questionnaire surveys between 2000 and 2010 (K. Wolter, unpublished data). Analyses were conducted for month for all vultures.

Results

The six vultures fitted with tracking units were all less than four years of age and all but one were tracked co was tracked for 101 days before the tracking unit stopped transmitting data. The six tracking units recorded high mean (± SE) accuracy of 2.4±0.02 PDOP (n = 4,326 locations).

Foraging ranges and distances travelled

The combined foraging ranges of all six vultures extended across extensive areas of southern Africa (Fig. 1 (± SE) of 56,683±9,210 km^2 (Table 1, Fig. 1A). MCPs included large areas that were never visited by the vu boundaries for three vultures (AG330, AG331 and AG350; Fig. 2A, B), but for the three widest ranging vultu 2C, D). Hereafter, unless otherwise stated, foraging range areas presented in the text are from GCR estima representation of the vultures' actual movements.

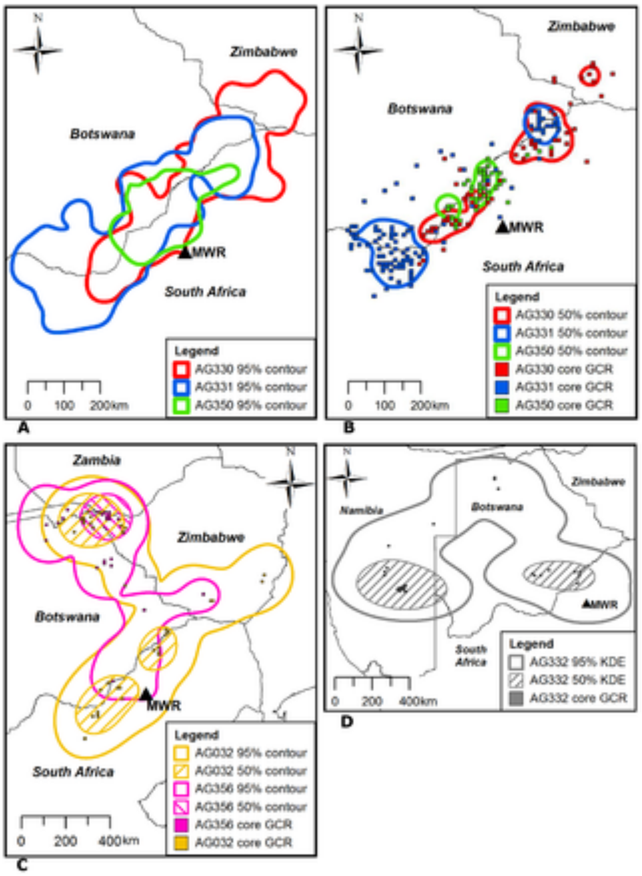

Figure 2. Overall and core foraging ranges for each individual.

95% KDE contours represent overall foraging ranges, 50% KDE contours and core GCRs represent cor for AG330, AG331 and AG350; (C) shows the foraging ranges for AG032 and AG356; (D) shows the for capture site is indicated by a black triangle and “MWR”.

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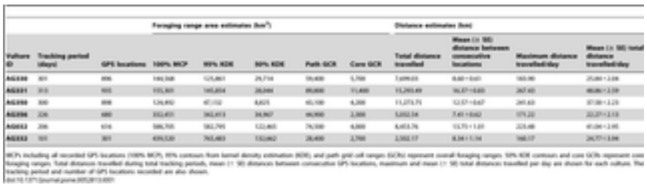


Vulture ID	Tracking period (days)	GPS locations	100% MCP	95% KDE	50% KDE	Path GCR	Core GCR	Total distance travelled	Mean (± SE) distance between consecutive locations	Maximum distance travelled/day	Mean (± SE) total distance travelled/day
AG330	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AG331	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AG350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AG356	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AG032	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AG332	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 1. Foraging range and distance estimates for six immature African white-backed vultures.
doi:10.1371/journal.pone.0052813.t001

Foraging range area curves from incremental area analysis reached asymptotes that lasted for at least 50 d
pattern of settled periods followed by exploratory movements beyond the existing MCP boundary occurred f
were asymptotic at the end of their tracking periods, indicating that the tracking periods were sufficient to pr
datasets for each of the six vultures were individually significantly autocorrelated, with a mean (± SE) Schoe

The mean (± SE) and maximum speed of all recorded moving (≥ 10 km·h^{-1}) GPS locations was 51.13±0.59
(± SE) distance travelled per day ranged from 22.27±2.13 km for AG356 to 48.86±2.59 km for AG331 (Table
day. AG331 travelled the furthest during the total tracking period, moving 15,293 km in 313 days. GPS locat
for three vultures. Following its capture, AG332 travelled north through Botswana before proceeding to sout
foraging range of 28,400 km^2 in 101 days (Fig. 2D). AG356 also travelled north immediately after capture, n
to the Victoria Falls region (17°55′S, 25°50′E) of Zimbabwe where it remained for a three month period (Fig.
south-west Angola, returning to north-east Zimbabwe through northern Botswana. After spending 3.5 month
Africa, AG032 travelled north through southern Zimbabwe to north-east Botswana and north-west Zimbabw
travelled over 8,454 km and occupied an overall range of 74,500 km^2, at one point moving 520 km across th
AG356 entered a total of five and six different countries, respectively (Fig. 2C).

The foraging ranges of the remaining three vultures (AG330, AG331 and AG350) extended across the Bots
orientated in a south-west to north-east direction from the Vryburg (21°03′S, 29°21′E) region of South Africa
south-west Zimbabwe (Fig. 2A). KDE and GCR analyses showed that these three vultures, as well as AG03
South Africa-Botswana border (Fig. 2B).

Monthly path GCR estimates ranged from 600 to 22,200 km^2 (mean ± SE = 9,878±846 km^2; n = 46 months)
estimates were recorded in May (Fig. 3). The five vultures that were tracked during both the wet summer (D
periods occupied significantly larger average monthly path GCRs during summer months (mean ± SE = 12,
(mean ± SE = 8,874±1,720 km^2; n = 5 vultures) (Wilcoxon signed-rank test: $Z = -2.20$, $p = 0.043$).

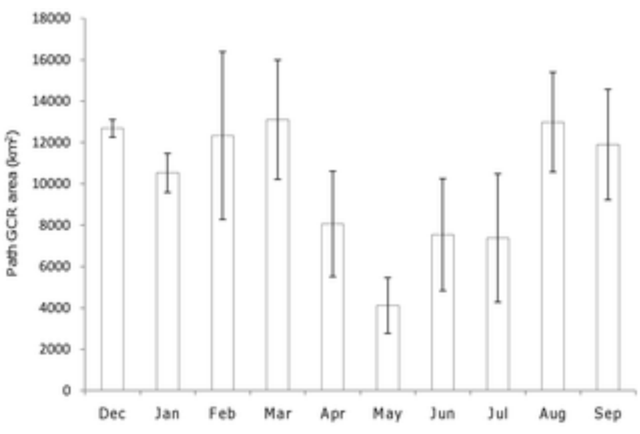


Figure 3. Mean (± SE) path GCR estimates for individual months for six immature African white-b

Due to differences in tracking periods for individuals, estimates were calculated for four vultures for Dece
September, inclusive.
doi:10.1371/journal.pone.0052813.g003

Utilisation of protected areas

Protected areas occupied a mean (± SE) of 4.33±1.50% of the 95% KDE contours of the three vultures that
the South Africa-Botswana border (AG330, AG331 and AG350), compared to 32.22±9.75% of the 95% KDE
Botswana and Zimbabwe (AG032 and AG356; Table 2). A mean (± SE) of 5.21±0.88% of stationary GPS lo
and AG350 were recorded inside protected areas, compared to 35.30±1.13% for AG356 and AG032 (Table
of the 50% KDE contours of AG330, AG331 and AG350, compared to 38.62±11.63% for AG356 and AG032

Vulture ID	Land use	Availability in 95% KDE (%)	Use at overall foraging range scale (%)	Use at core foraging range scale (%)
AG330	PA	7.20	6.90	4.63
	Non-PA	92.80	93.10	95.37
AG331	PA	2.12	3.97	0.00
	Non-PA	97.88	96.03	100.00
AG350	PA	3.66	4.76	4.82
	Non-PA	96.34	95.24	95.18
AG356	PA	41.97	34.16	50.25
	Non-PA	58.03	65.84	49.75
AG032	PA	22.47	36.43	26.99
	Non-PA	77.53	63.57	73.01
AG332	PA	27.56	8.72	4.66
	Non-Pa	72.44	91.28	95.34

The proportion of each vulture's 95% KDE contour occupied by protected areas defined their availability to each vulture. At the overall foraging range scale use of protected areas was defined as the proportion of stationary (i.e. <10 km·h⁻¹) GPS locations within the 95% KDE contour that were recorded inside protected areas. The proportion of each vulture's 50% KDE contours occupied by protected areas defined their use at the core foraging range scale.
doi:10.1371/journal.pone.0052813.t002

Table 2. Availability and use of protected areas by six immature African white-backed vultures at
doi:10.1371/journal.pone.0052813.t002

At the overall foraging range scale Ivlev's electivity index values (Fig. S2A) indicated that more stationary G
expected for three vultures, while fewer than expected were recorded inside protected areas for the other tw
values (Fig. S2B) indicated that protected areas occupied a similar proportion of the 50% KDE contours to t
smaller proportion of the 50% KDE contours than expected for the other two. Protected areas were complet
in an Ivlev's electivity index value indicating maximum avoidance.

South African protected areas were not visited regularly by any vultures (Fig. 4A), with AG032 never enterin
months. Pilanesberg NP (25°14′S, 27°05′E) and other relatively large conservation areas in the North West
by any of the vultures, while only two and five stationary locations (both from AG331) were recorded inside l
NP (24°24′S, 27°35′E) respectively. None of the three vultures that spent the majority of their tracking perioc
periods inside protected areas.

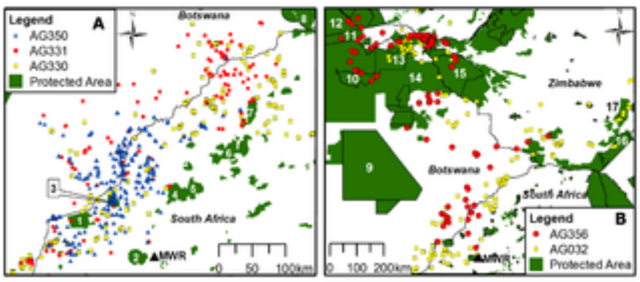


Figure 4. Stationary GPS locations of immature African white-backed vultures in relation to prote
(A) shows stationary GPS locations from AG330, AG331 and AG350 in relation to protected areas in the
= Madikwe GR; 2 = Pilanesberg NP; 3 = Atherstone NR; 4 = Marakele NP; 5 = Welgevonden NR; 6 = La

Tuli conservation area. (B) shows stationary GPS locations from AG356 and AG032 in relation to protec
NP; 10 = Moremi GR; 11 = Caprivi GR; 12 = Luiana NP (Angola); 13 = Chobe NP; 14 = Wildlife Manage
= Save Conservancy. Protected area data are from WDPA [32], [33].
doi:10.1371/journal.pone.0052813.g004

The two vultures that travelled more extensively through southern Africa visited protected areas more regul Zimbabwe in the Kavango-Zambezi Transfrontier Conservation Area (TFCA), where they spent extended pe 24°43′E) and associated wildlife management areas (WMAs) in northern Botswana, as well as in the Victori spent an 8 day period passing through the Okavango-Moremi protected area in northern Botswana (19°19′S were not calculated for AG332 due to its limited tracking period.

Utilisation of supplementary feeding sites

Excluding AG332 which did not visit a supplementary feeding site after leaving the capture site, the proporti feeding sites for each vulture were 1.81% for AG330, 0.84% for AG331, 26.68% for AG350, 22.72% for AG and 4 feeding sites each (mean ± SD = 3.40±0.89), totalling 8 different sites including the MWR capture site Zimbabwe, and one was south-east of Gaborone in Botswana. The remaining 5 sites were in the North Wes re-visited by any of the vultures fitted with tracking units after they left the capture site.

Two of the vultures spent a relatively large proportion of their time each month in the vicinity of supplementa stationary GPS locations per month being recorded within 1 km of feeding sites for AG350 and AG356, resp privately managed supplementary feeding site approximately 16 km south-east of Gaborone, Botswana (24 locations within 1 km of that site. From April until July AG356 regularly utilised a site approximately 16 km s with 15.42% of its stationary GPS locations recorded within 1 km of that site. The same vulture was also reg several kilometres west of Victoria Falls town at Victoria Falls Safari Lodge (17°54′ S, 25°48′E), where it was number. There was a significant negative correlation between the area of monthly path GCRs and the propo supplementary feeding sites ($r_{s\ (24)}$ = −0.674, p<0.001, n = 24 months), indicating that the vultures traverse feeding sites for longer periods.

Discussion

This study provides the first description of ranging patterns of immature African white-backed vultures track foraging range estimates varied markedly between methods, emphasising the need to use appropriate met study [27]. As seen previously, MCPs and, to a lesser extent, KDE contours included large areas that were ranging individuals [28], [38]. Path GCRs reduced the inclusion of unvisited areas and produced the most re the vultures' movements. The spatial extent of core GCRs and 50% KDE contours corresponded closely an *ad hoc* method of bandwidth selection and GCR methods should both be considered suitable for the analys

In general, foraging range size among vertebrates is inversely related to resource abundance and spatio-te relatively long distances travelled by the vultures within their range boundaries indicate that the distribution unpredictable and sparse, as expected [2], [4]. The maximum distances that the vultures travelled in a singl capable of searching for carcasses across a vast daily foraging range and that vultures present at a carcass Although the large overall foraging ranges recorded during this study were expected because immature *Gy* one food source to another [1], [4], the long distance movements from the capture site made by three of the tracking periods. These results and re-sightings of marked individuals more than 900 km from their natal ori vultures are able to disperse widely across southern Africa, possibly to avoid competing with adults for the s

Although very few foraging range estimates exist for immature African white-backed vultures, and African v mean home range of 482276 km^2 for two immature Cape vultures (*G. coprotheres*) (one was a possible *G.* satellite tracking data in Namibia [20]. The foraging range estimates in our study are substantially larger tha vultures in the Western Cape Province of South Africa obtained from landowner questionnaires and radio-tr population in the Drakensberg mountains obtained from re-sightings of marked individuals [42]. Comparisor differences in environmental conditions and foraging ecology of the different study species, and the method: provide a much better representation of the vultures' movement patterns [27]. The foraging range estimates substantially larger than those from similar GPS tracking studies on *Gyps* species in Asia (mean MCP = 24' MCP = 7419 km^2 for eight *G. fulvus* [44]), and were therefore some of the largest recorded for any *Gyps* vul speeds of travel correspond to early estimates for *Gyps* vultures in the Serengeti [3], [40].

Although Ivlev's electivity index values indicated that three vultures spent more time inside protected areas t proportion to their availability, only a small proportion (<5%) of stationary GPS locations were recorded insic AG350). The low availability (<4%) of protected areas in the 95% KDE contours of both vultures probably ca high degree of positive selection despite use only marginally exceeding availability [34]. The limited amount areas indicates that they were able to locate sufficient carcasses to meet their energy requirements by regu although the creation of relatively new wildlife reserves such as Pilanesberg National Park and Madikwe Ga benefit vultures in northern South Africa [45], there is an urgent need to implement vulture conservation mea network. The ungulate populations inside many of the fenced protected areas in northern South Africa are r large carnivores such as lions (*Panthera leo*) rather than other causes of mortality such as malnutrition [46], that die from causes other than predation and rarely land at carcasses with large carnivores in attendance [this study could be partially explained by lower food availability and elevated levels of competition in fenced carnivores compared to the much larger protected areas of northern Botswana and Zimbabwe [46].

The geographical distribution of protected areas in northern South Africa might also have reduced their acce large protected areas within the foraging ranges of the vultures were located in mountainous areas (e.g. the by all of the tracked vultures (Fig. 4A). As African white-backed vultures favour flat, lowland savannah [4] it i are located in areas lacking suitable environmental characteristics (e.g. topography) for efficient foraging ac

More than 34% of stationary GPS locations of the two vultures that travelled more widely through southern / inside protected areas, all of which were outside South Africa. Both vultures spent extended periods in the l reserves outside South Africa, where ungulate densities are higher than surrounding unprotected land and c support previous suggestions that vultures regularly use protected areas in Botswana and other African cou disturbance and higher food availability compared to unprotected areas [13]–[15], [51], but also show that th periods outside protected areas.

The vultures' core foraging ranges (Fig. 2) were located in areas known to be important for African white-ba rates for the species recorded during ground surveys [4], [52]. The distribution of ungulate carcasses was p movement patterns of the immature vultures because their principal activity would have been searching for within a certain distance of a nest site [4], [53]. Farming of wild and domestic ungulate species is common a Botswana, where several of the vultures spent a large proportion of their time [54], [55]. It is likely, therefore domestic ungulate species, as previously seen in the study area and elsewhere in South Africa [56], [57]. Th recorded during this study might have been caused by higher mortality rates of wild ungulate species during vultures to locate carcasses in smaller foraging ranges. Although mortality rates of domestic livestock are ge carcasses are more likely to be found and removed by farmers on commercial livestock farms than on more vultures might also be forced to travel further during the wet summer months when increased vegetation ca possible to verify the purpose of the vultures' movements, however, and, as with previous studies that recor the underlying causes remain unclear but merit further investigation [20], [43].

Two vultures were regularly recorded in the vicinity of specific supplementary feeding sites that they repeate were able to obtain a large proportion of their food requirements at those sites. *Gyps* vultures frequently use [17], [20], and the provision of supplementary food at fixed locations has been shown to reduce vulture forag study, with smaller monthly foraging ranges recorded during months when the vultures spent a greater prop not all of the vultures were regularly recorded in the vicinity of feeding sites, it is possible that they visited fe this analysis, and so these estimates might be conservative. Further research is required to determine the u Africa, and their potential impacts on vulture foraging ecology and conservation [18].

The small sample size (*n* = 6) and relatively short tracking periods (101 – 313 days) limited by financial and

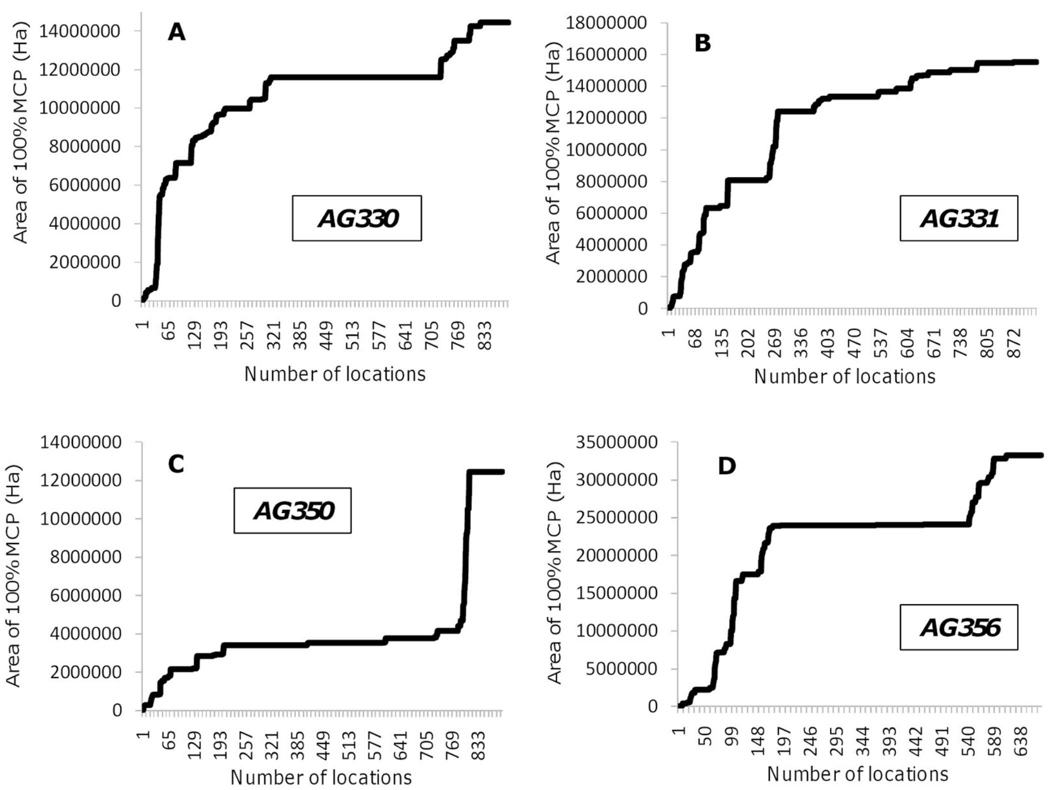
considered with some caution. It was also not logistically feasible to verify the activities of the vultures on th
frequent long distance movements. However, despite these limitations the regular sampling intervals and hi
insight into patterns of space use by immature African white-backed vultures in southern Africa. For conser
investigations into the movement patterns of adult African white-backed vultures as their rates of survival ar
into the future [17]. It has been estimated that 50% mortality before maturity would lead to only 4.5% adult r
least 22 years to replace themselves [21]. With such long breeding life requirements, even minimal change
entering adulthood could result in population declines.

Conclusions

We have found that immature African white-backed vultures are capable of travelling across the entire regio
time outside protected areas. Although based on a small sample size, these findings may have important im
vultures. If the ranging patterns recorded during this study are repeated across the wider population, then in
be be exposed to the full range of threats in southern Africa. Their limited use of protected areas and regula
leaves them susceptible to anthropogenic threats such as poisoning by veterinary NSAIDs or predator contr
southern Africa therefore pose a serious threat to vulture populations from all countries in the region, and c
required to confront the problem. Our results indicate that monitoring and management of the availability an
vital for vulture conservation in southern Africa. The findings from this study also demonstrate that GPS trac
information about vulture movements and land use selection, and as a tool to inform the planning of vulture
adult African white-backed vultures and all other declining vulture species throughout Africa.

Supporting Information

Figure_S1.tif



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Foraging range area curves from incremental area analysis of GPS locations from six immature African white-backed vultures. The number of GPS locations used to generate MCPs by adding consecutive locations until all locations were used is plotted against the area of each MCP. (A) – (F) represent different vultures.

Figure S1.

Foraging range area curves from incremental area analysis of GPS locations from six immature Afri
used to generate MCPs by adding consecutive locations until all locations were used is plotted against the a

(TIF)

Figure S2.

Ivlev's electivity index values for protected (PA) and unprotected (Non-PA) areas for five immature A core foraging range scales. Availability was represented by the relative proportions of protected and unpro overall foraging range scale (A) use was represented by the proportion of each vulture's stationary GPS loc the core foraging range scale (B) use was represented the relative proportions of protected and unprotectec electivity index values range from −1 to +1, with zero indicating use in proportion to availability, while positiv expected, respectively.

(TIF)

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Author Contributions

Acted as the first author's study supervisor: VN SGW. Conceived and designed the experiments: WLP SGW the data: WLP SGW. Wrote the paper: WLP SGW VN.

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