White-backed Vulture *Gyps africanus* parental care and chick growth rates assessed by camera traps and morphometric measurements

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Abstract

Persistent vulture declines across Africa are a cause for concern as the number of species threatened with extinction increases. The White-backed Vulture *Gyps africanus* was, until recently, considered abundant but has been declining rapidly in recent years due to various threats including decreasing food availability. We used camera traps to investigate nest attendance and food provision at the nests of White-backed Vultures in north-eastern Swaziland. Chick age influenced brooding behaviour of the parents, with a reduction in brooding time as the chick aged. Mean food provision rate by parents to the nestling was 0.7 bouts/day, which was mostly delivered between 09:00 and 15:00. Contrary to expectations, provisioning rates did not increase with age of the chick despite both adults delivering food. The growth of chicks showed a curvilinear relationship with age for the first 100 days with the tarsus and bill reaching maximum length after 80 days. We recommend further research into the availability of food for breeding vultures in order to understand the emerging threat of declining food availability in Africa. .

Key words: Swaziland, *Gyps africanus,* camera traps, growth curves

Introduction

Vultures are amongst the most misunderstood and underappreciated birds of prey in many cultures (Sekercioglu 2006, Ogada and Keesing 2010) and as a result they are persecuted and hunted for use in traditional medicine, particularly in Africa (Ogada et al. 2012a, Ogada 2014). Vultures are also vulnerable to poisoning, electrocution or collision with electrical infrastructure, disturbance at nest sites, habitat loss and declining food availability (Ogada et al. 2016). These threats have caused severe declines of vulture populations across Africa that are comparable to the declines observed in Asia which raises concerns in light of the ecosystem services provided by vultures (Markandya et al. 2008, Ogada et al. 2016).

As obligate scavengers, vultures are clearly well adapted for a scavenging lifestyle (Ruxton and Houston 2004), a feature illustrated in the speed by which they are able to locate and devour carcasses scattered across vast landscapes (Houston 1974a). Important adaptations for this lifestyle include excellent eyesight that allows them to spot carcasses from great heights and energy efficient soaring flight through which they search large areas at minimal cost (Houston 1974a, 1974b, Phipps et al. 2013, Kane et al. 2016). Foraging vultures keep an eye on other vultures and avian scavengers, resulting in large numbers of birds descending down onto a carcass soon after its discovery (Houston 1974a, Spiegel et al. 2013, Kane et al. 2014). Further, vultures play a critical role in curbing the spreading of diseases amongst mammalian carnivores and ultimately to humans, by minimizing the time carcasses spend in the open (Markandya et al. 2008, Ogada et al. 2012a, Ogada et al. 2012b).

Until recently, White-backed Vultures *Gyps africanus* were abundant and widespread across the African continent (Mundy et al. 1992). However, this species, like other African vultures, has been declining rapidly (Ogada et al. 2016) and as a result is currently listed as Critically

Endangered (BirdLife International 2015). Whilst the catastrophic decline of *Gyps* vultures in Asia was attributed to poisoning through the use of diclofenac to treat livestock (Oaks et al. 2004), the situation in Africa differs in that each region has a unique set of threats (Ogada et al. 2016). Hence, a threat affecting vulture populations in one region may not be important in another region. In Swaziland for example, the White-backed Vulture is thought to be threatened by habitat loss and declining food availability, particularly through the transformation of natural landscapes to agricultural plantations (Monadjem 2001, Monadjem et al. 2003, Monadjem and Garcelon 2005).

The threat of declining food availability is poorly understood, partly because of the difficulty in quantifying it given the ability of vultures to forage over wide areas (Bamford et al. 2007, Phipps et al. 2013, Kane et al. 2016). Thiollay (2006) observed that in West Africa livestock carcasses were rarely left out for vultures as was the case three decades earlier. Changes in farming practices and rapidly declining numbers of large ungulates in parks has also contributed to the decrease of food available to vultures (Thiollay 2006). Breeding vultures are particularly at risk because, in addition to feeding they also need to provision a chick in the nest (Houston 1976). Komen (1991) showed that Cape Vulture nestlings' gross energy intake increases for the first 85 days suggesting a high demand by the growing chicks during the early stages of the nestling period. Areas of high food availability are associated with high vulture activity (Murn and Anderson 2008). Therefore measuring provisioning rates to chicks may give valuable clues about the availability of food for vultures in a region where the direct quantification of food availability is otherwise a challenge. The aim of this study was to use relatively unintrusive technology, namely camera traps, to monitor activity at White-backed Vulture nests. The objectives of our study were to: 1) investigate the relationship between brooding time and age of chick; 2) determine food provision rates at White-backed Vulture nests, and 3) produce growth curves for chicks in the nest.

Materials and methods

Study area

The study was conducted at Mlawula Nature Reserve (26°11'S, 31°01'E) in north-eastern Swaziland. Vultures in this reserve breed along a 16 km stretch of the Siphiso River that runs through the Siphiso Valley (Monadjem 2001, 2003a, 2003b). In general the vegetation in the reserve is dominated by *Acacia* trees but the riparian vegetation along the Siphiso River supports tall non-deciduous tree species like, *Schotia brachypetala* and *Combretum imberbe* which are usually selected for nesting by White-backed Vultures (Monadjem 2003a).

Data collection

The Siphiso River was surveyed on foot for active nests which were identified by the presence of an adult on the nest or by the presence of "white wash" on the ground underneath it. We used a Garmin Geographic Positioning System (GPS) to take the coordinates of each active nest. We also recorded the height of the nest and the tree species in which the nest was located.

Seven motion sensitive camera traps (Primos TRUTH CAM 35, model No: 63010 http://www.primos.com/products/game-cameras/) were used to monitor brooding behaviour and food provisioning to chicks on seven nests. Cameras were installed at least 1 m from the edge of the nest (Table 1). All cameras were motion activated and were set to normal sensitivity with 10 s delay between photographs over a 24-hour period. Photographs were stored on 32 GB SD memory cards that were changed every 14 days at which time the

Table 1: Outcome of seven White-backed Vulture nests during the 2014 breeding season as assessed by camera traps.

Nest number	Tree species	Nest height (m)	Camera distance from nest (m)	Successful (Y/N)	Cause for nest failure
1	*Schotia brachypetala*	14	3.5	No	Failed to hatch after 70 days incubation
2	*Vachellia robusta*	15	1.4	Yes	Successful
3	*Combretum imberbe*	15	1.2	No	Bad weather. Nest collapsed with 2-day old chick
4	*Schotia brachypetala*	12	1.8	No	Unknown
5	*Schotia brachypetala*	13	1.2	Yes	Successful
6	*Schotia brachypetala*	12	2.0	Yes	Successful
7	*Schotia brachypetala*	18	2.5	No	Unknown

photographs were downloaded to a laptop. Standard body measurements were taken from each chick every 14 days until the chick fledged. The chicks were measured from 12, 39 and 40 days of age and measurements included mass (taken to the nearest g) and length of wing, tarsus, bill, head and tail (taken to the nearest mm). A nest visit lasted 20-30 min except during ringing and tagging when it took 45 minutes. All measurements were carried out following the guidelines provided in the SAFRING bird ringing manual (De Beer et al. 2001).

Data analysis

Statistical tests were performed using MINITAB statistical software (Release 13.32, www.minitab.com). Means were reported with standard deviations (±SD). All photographs captured by the camera traps were observed individually, and information about when a bird arrived or departed from the nest was obtained from the date and time stamp on the photographs. To assess brooding behaviour we used the cameras set on the three successful nests, which had an average of 104 camera-days per camera (see Table 4 for further information).

Since the camera could miss the adult when it was perched in the tree behind the camera or on branches that were not within view, brooding time was limited to when the bird was actually sitting on the nest. A feeding bout was confirmed by pictures showing the adult feeding the chick or by noting the change in the size of the crop of both the chick and the adult. Observed feeding bouts at the three nests were combined and then divided into four diurnal 3-hour blocks (06:00-09:00, 09:00-12:00, 12:00-15:00 and 15:00-18:00). Growth curves were produced using non-linear models from White-backed Vulture chicks that were monitored from ages 12, 39 and 40 days. The exact hatching dates were not known but they were estimated from the wing measurements (Mundy 1982).

Results

Breeding behaviour

Data loss did occur due to mechanical failure of one camera which had to be replaced. On another nest, data loss was due to a faulty SD card. Of the seven nests that were monitored with camera traps, three successfully raised a chick to fledging. The other four nests failed during incubation or early in the chick rearing stage (Table 1). The egg that failed to hatch was incubated for 70 days before the parents eventually ceased incubation. Another nest collapsed during a storm and resulted in the death of a 14-day old chick. The cause of nest failure of the other two nests could not be verified because of the data loss mentioned above.

Male and female adults took turns attending the nest as they could be seen switching over at the nest, despite the fact that the sexes could not be distinguished. Change overs always took place during the day and lasted for less than 1 min. Mean brooding time at the three nests was 5.5 ± 3.7 hours. The exponential model showed that time spent by the adults at the nest decreased as the chick got older (Figure 1). Once the chicks reached 60 days of age or older, the adults spent less than 3 hours attending the nest. The earliest arrival time of the non-incubating adult at nest was 05:11 and the latest departure time from the nest was 17:46.

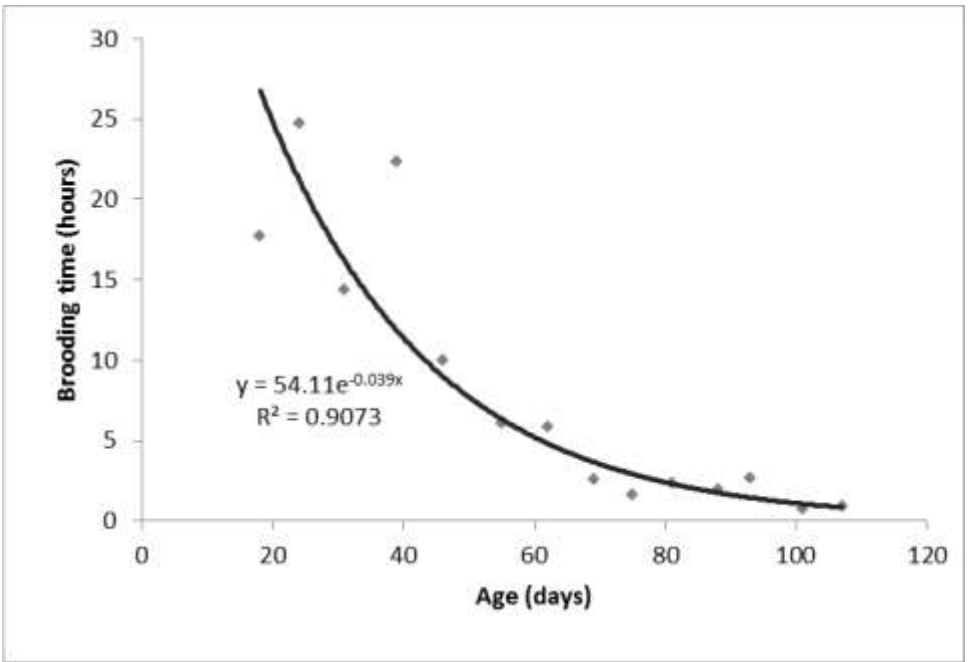


Figure 1: Change in average brooding time by age of three White-backed Vulture chicks in north-eastern Swaziland. Chicks fledged at an average age of 119 days.

Chicks were fed at a mean rate of 0.70 ± 0.24 bouts/day. For most of the feeding bouts, the adults regurgitated food directly into the mouth of the chick as opposed to regurgitating onto the nest. The food fed to the chicks could not be identified or quantified from the photographs. Even though the food could not be identified, the food was either "fresh red meat" or "whitish food". Fresh red meat was usually brought in when the parents had returned from foraging and they fed the chick immediately upon arrival. The source of the "whitish food" could not be ascertained from photographs as it also depended on which part of the carcass was consumed. There were few instances where chicks were fed pieces of bone. Overall there was no significant difference in the mean number of feeding bouts per day at the three nests ($F_{0.05, 2, 9}$ = 2.65, P= 0.125, Figure 2). However when extreme hours of the day (06:00-09:00 and 15:00-18:00) were compared to the middle hours of the day (09:00-15:00), there was a significant difference in the number of feeding bouts observed; chicks were fed at a higher rate during the middle hours than the extreme hours of the day (t= 2.64, P= 0.046, df= 5). There was no correlation between food provision rate and chick age (r= 0.2, P= 0.431, Figure 3).

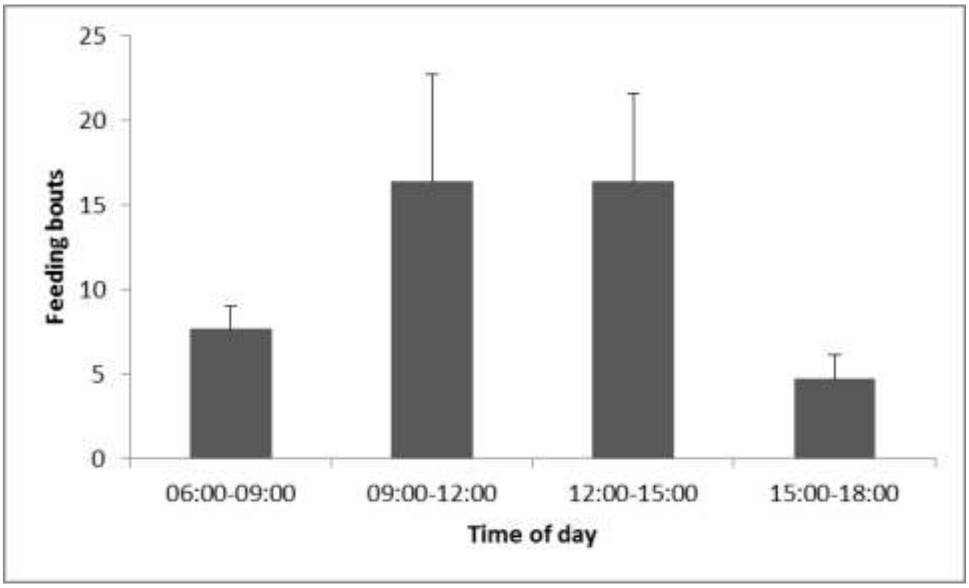


Figure 2: Observed feeding bouts at three White-backed Vulture nests grouped into 3-hour time blocks.

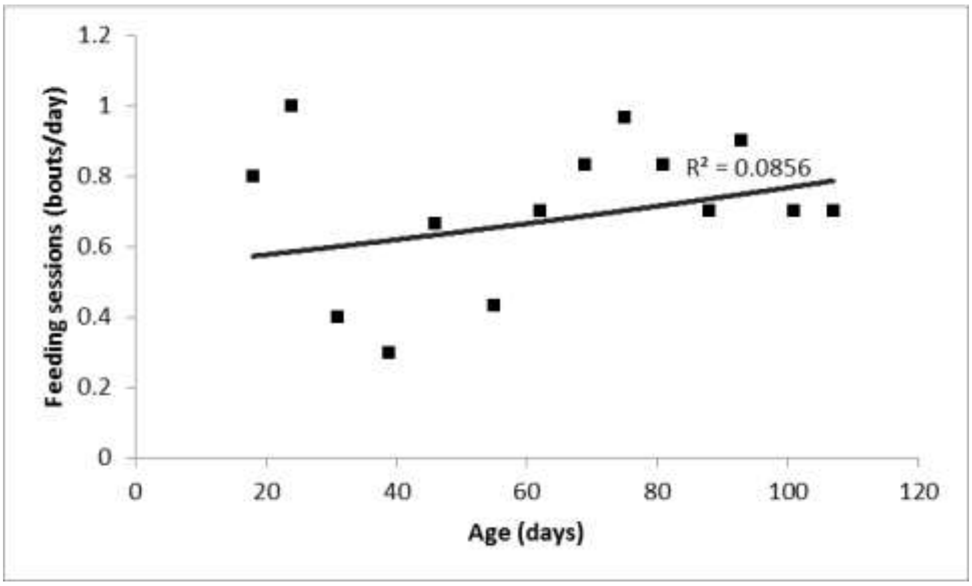


Figure 3: Relationship between food provision rate and age of three White-backed Vulture chicks in north-eastern Swaziland.

Growth curves

Each of the measurements showed similar growth patterns across the three chicks: mass ($F_{0.05, 2, 16}$= 3.39, P= 0.0592,), wing ($F_{0.05, 2, 16}$= 0.671, P= 0.525,), tarsus ($F_{0.05, 2, 16}$= 1.31, P= 0.297), bill ($F_{0.05, 2, 16}$= 1.18, P= 0.333), head and bill ($F_{0.05, 2, 16}$= 1.47, P= 0.260) and tail ($F_{0.05, 2, 16}$= 1.08, P= 0.371). Chicks fledged at a mean age of 119 days. Last mean growth measurements were taken at the age of 107 days (the latest age at which measurements could be taken without the risk of the chicks fledging early), and these are reported with their standard deviations in Table 2. Data from the different measurements taken showed significant correlation in the growth of tarsus versus head and bill (r= 0.999, P= 0.000), mass versus wing (r= 0.999, P= 0.000), tarsus versus bill (r= 0.989, P= 0.000), wing versus tail (r= 0.915, P= 0.029) and bill versus head and bill (r= 0.999, P= 0.000). There was a curvilinear relationship between mass gain and age of the chicks for the first 100 days (Figure 4 c). A similar trend was observed with the growth of wings and the tail (Figure 4 a and b). Mean growth rates of wing, tail and mass were 5.1 ± 2.9 mm/day, 3.6 ± 1.7 mm/day and 0.046 ±

0.02 kg/day, respectively. The graphs of tarsus and bill were also curvilinear but reached the asymptote at 80 days of age (Figure 4 d-f). For the linear portions of the graphs of tarsus, bill, and head and bill the mean growth rates were 0.98 ± 0.86, 0.42 ± 0.19 and 0.93 ± 0.4 mm/day, respectively (Table 3).

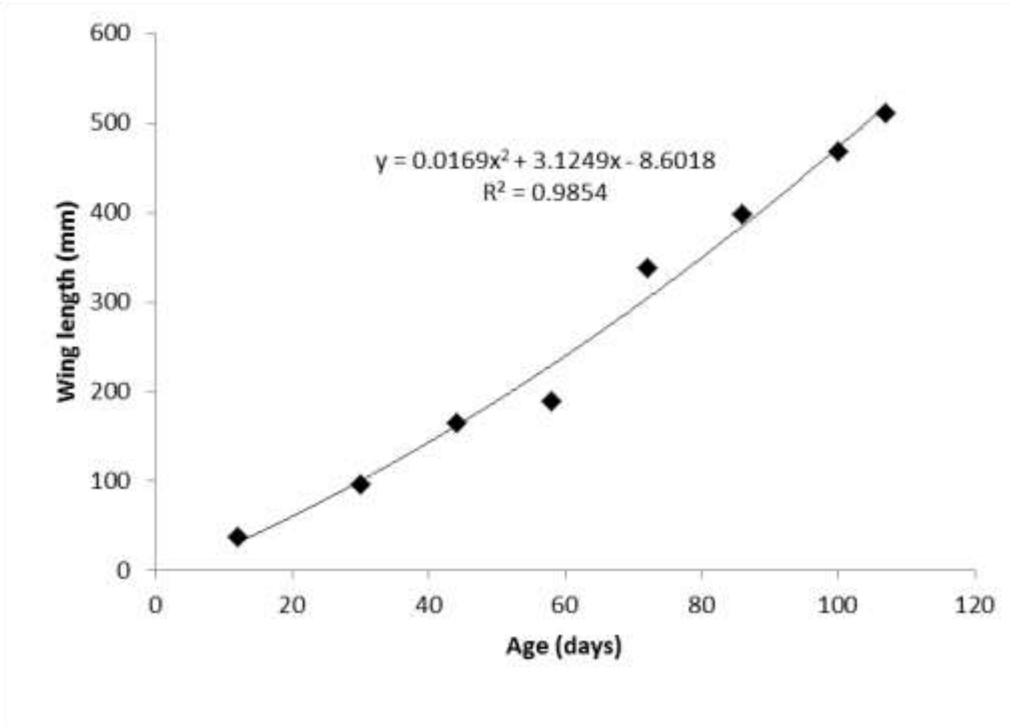
Table 2: Last mean biometric measurements ± SD taken prior to fledging. Chicks fledged when they were 119 days old, n= 3.

Age (days)	Mass (g)	Wing (mm)	Tarsus (mm)	Bill (mm)	Head and Bill (mm)	Tail (mm)
107	4826.7 ± 320	489 ± 40.6	115.03 ± 1.72	62.3 ± 1.06	131.7 ± 4.25	230 ± 35.0

Table 3: Growth rates ± SD of White-backed Vulture chicks. Growth rates reported are for the linear portions of the graphs (n= 3), since graphs of bill, head and bill, and tarsus were not linear throughout.

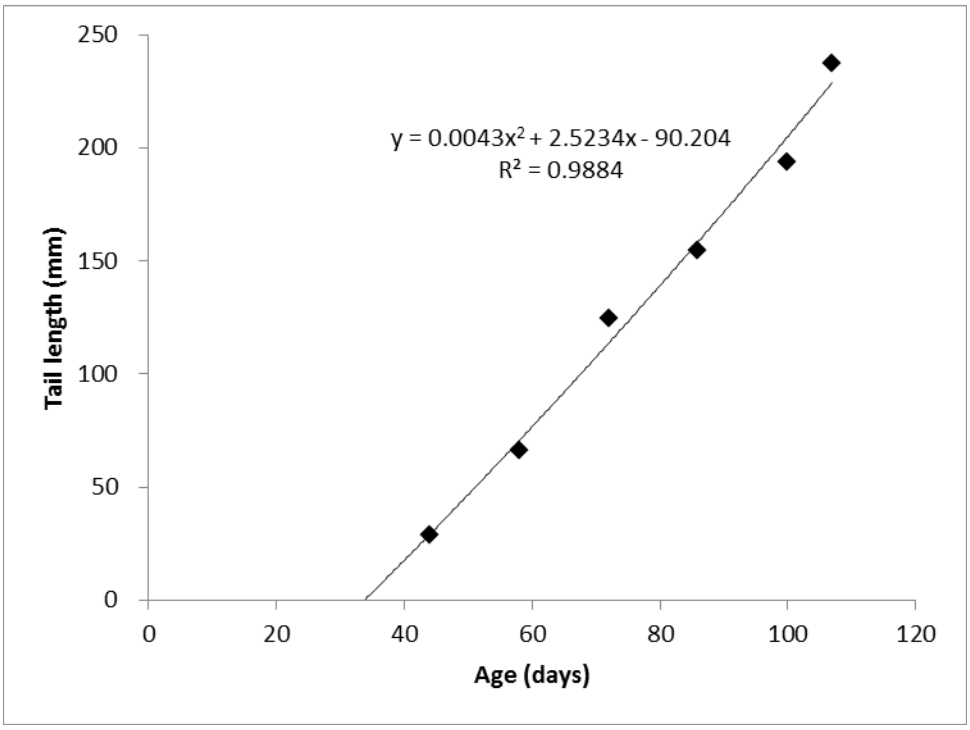
Mass (kg/day)	Wing (mm/day)	Tarsus (mm/day)	Bill (mm/day)	Head and Bill (mm/day	Tail (mm/day)
0.046 ± 0.021	5.1 ± 2.8	0.98 ± 0.86	0.42 ± 0.19	0.93 ± 0.4	3.6 ± 1.7

A



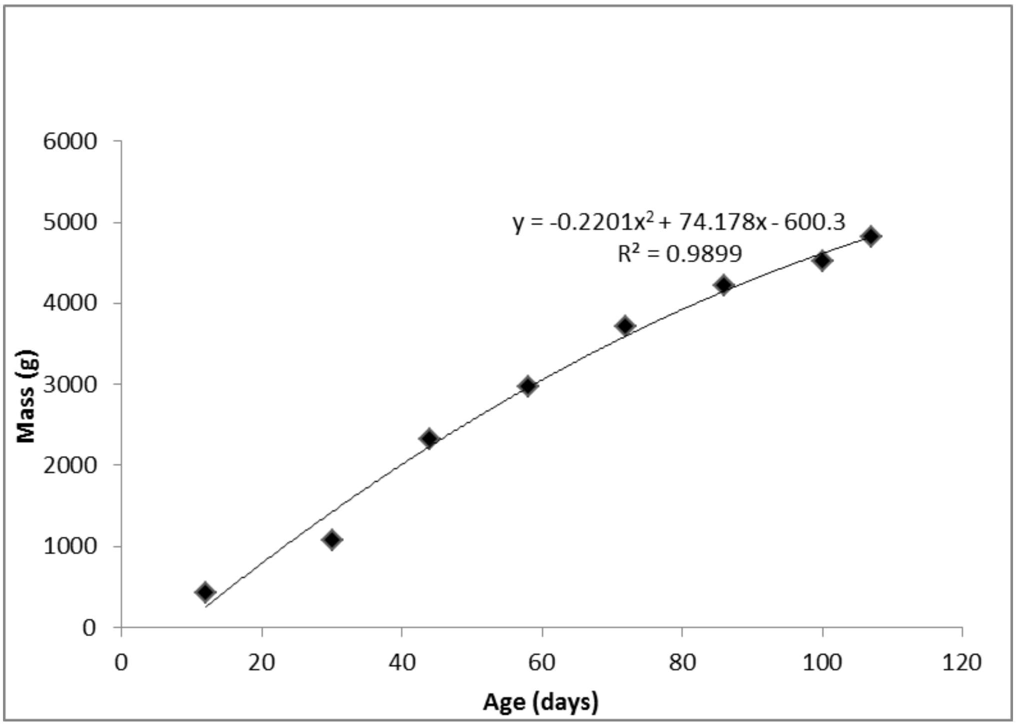
600
500
400
300
200
100
0
Wing length (mm)
y = 0.0169x² + 3.1249x - 8.6018
R² = 0.9854
0
20
40
60
80
100
120
Age (days)

B

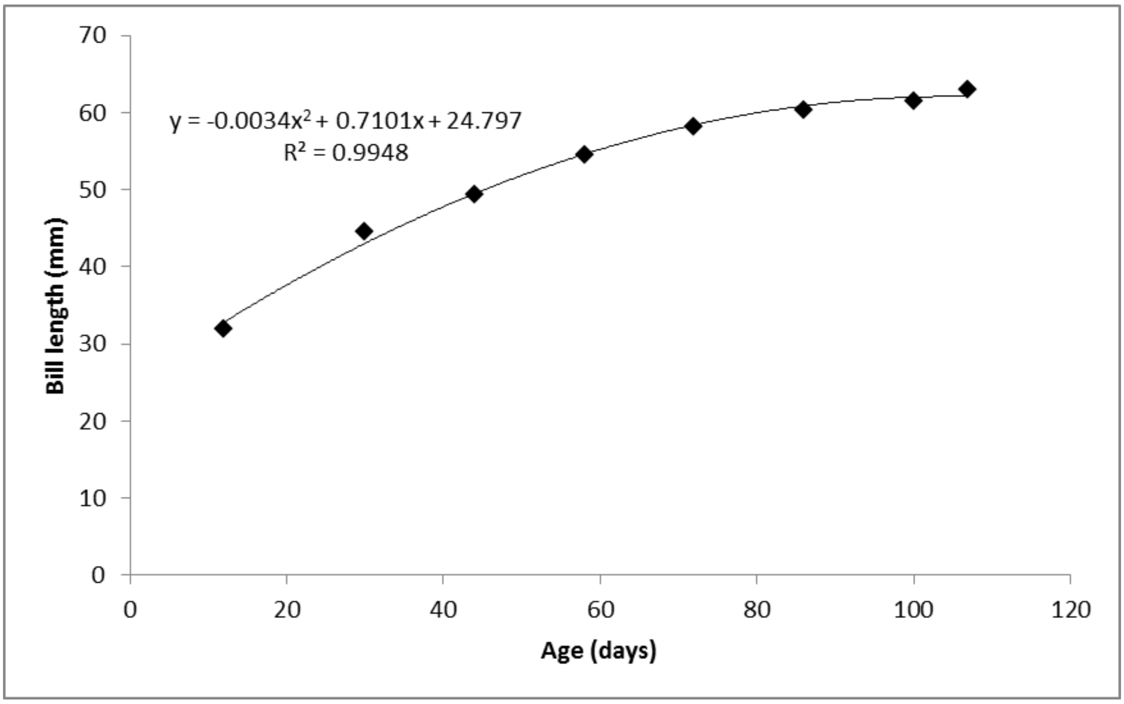


250
200
150
100
50
0
Tail length (mm)
y = 0.0043x² + 2.5234x - 90.204
R² = 0.9884
0
20
40
60
80
100
120
Age (days)

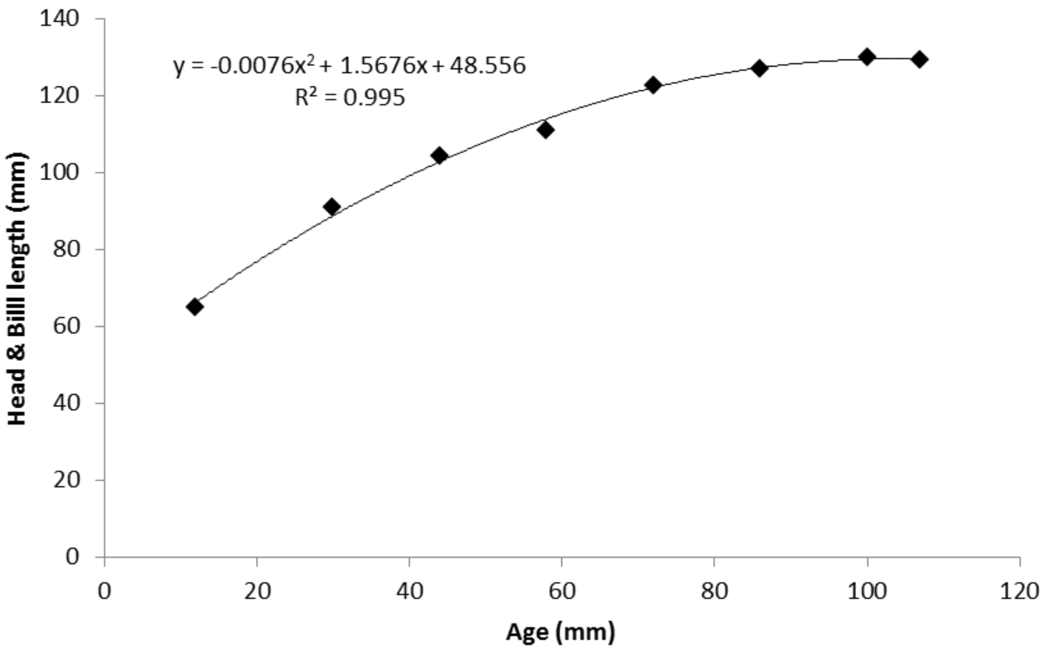
C


y = -0.2201x² + 74.178x - 600.3
R² = 0.9899
6000
5000
4000
3000
2000
1000
0
Mass (g)
0
20
40
60
80
100
120
Age (days)

D


y = -0.0034x² + 0.7101x + 24.797
R² = 0.9948
70
60
50
40
30
20
10
0
Bill length (mm)
0
20
40
60
80
100
120
Age (days)

E



F

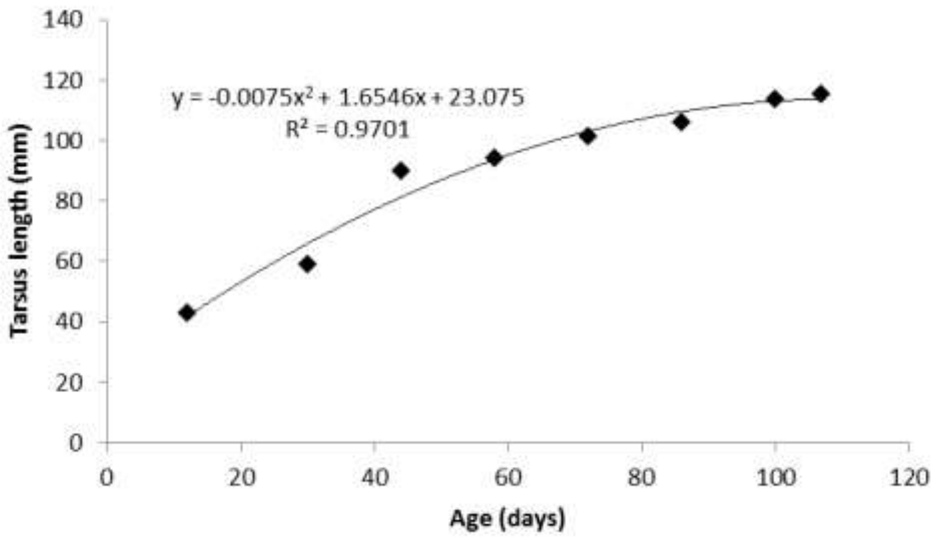


Figure 4: Growth curves of White-backed Vulture chicks measured in north-eastern Swaziland: Wing (a), Tail (b), Mass (c), Bill (d), Head and Bill (e) and Tarsus (f) (n= 3).

Table 4: Camera trapping effort at White-backed Vulture nests in Mlawula Nature Reserve, Swaziland. Nests used for analyses are shown in bold.

Nest number	1	**2**	3	4	**5**	**6**	7
Camera trap days	59	**110**	7	34	**110**	**92**	5
Days without data	16	**36**	0	4	**1**	**24**	1

Discussion

The model showed that during chick rearing, adult White-backed Vultures spent greater time at the nest when the chick was young, but progressively reduced brooding time with the age of the chick. Mundy (1982) suggested that reasons for this trend have to do with protection from predators and thermoregulation. Parents have to protect the chick from potential predators, like the Bateleur *Terathopius ecaudatus* and Pied Crow *Corvus albus*, which might predate nests while the adults are away (Mundy 1982). Hatchlings need to be kept warm at night and need to be provided with shade during the day. Normally adults stay at the nest to provide warmth and shade until the chicks are sufficiently feathered to thermoregulate (Xirouchakis and Mylonas 2007). Katzenberger et al. (2015) reported temperature to be an influential weather variable in determining breeding behaviour of Black Sparrowhawks *Accipiter melanoleucus*. When temperatures were low adult Black Sparrowhawks spent a greater amount of time in the nest brooding, especially when the chicks were still young and could not thermoregulate (Katzenberger et al. 2015). The mean 5.5 hours brooding time reported in this study is an underestimate because monitoring at the nest only started when the chicks were 12 days old and adults are expected to spend long hours at the nests during the first few days after hatching. Generally nest attendance is continuous for the first two months after hatching (Xirouchakis and Mylonas 2007) even though the attending bird may not be necessarily on the nest the whole time, but may be watching from a distance in the vicinity of the nest (Mundy 1982). This is also supported by the early arrivals in the morning and the late departures in the afternoon.

Kendall (2014) found that in East Africa, White-backed Vultures and Rüppell's Vultures were amongst the avian scavengers that were usually abundant at carcasses during morning hours and were satiated by the afternoon. It was therefore an expected outcome to have many feeding bouts recorded between 09:00 and 15:00, suggesting successful foraging. White-backed Vultures are thought to utilize early morning thermals so that they are present in high abundance in the morning (Kendall 2014). The overall mean food provisioning rate was 0.7 bouts/day which is lower than the 1.9 bouts/day reported by Xirouchakis and Mylonas (2007) for the Eurasian Griffon *Gyps fulvus* in Crete (Greece). One reason for this might be related to differences in food availability in the two environments. Alternatively, the amount of food provisioned by White-backed Vultures per visit in this study may have been greater than that provisioned by Eurasian Griffons in Crete. However, we were not able to estimate the amount of food per visit and therefore we cannot distinguish between these two explanations. McPherson et al. (2016) reported a comparable maximum provisioning rate of 0.8 prey/day for breeding Crowned Eagles *Stephanoaetus coronatus,* which is a predator of medium-sized mammals and birds as opposed to a scavenger.

Growth curves produced from biometric data showed a curvilinear relationship with age especially in mass and the growth of wings and tail. Mundy (1982) suggested that chicks prioritise the growth of wings and primary feathers and therefore most of the food resources go towards the development of the wings and any extra food is converted to fat, thus increasing body mass. The same pattern was observed in this study where the chicks seemed to prioritize the growth of flight-related parts (probably to prioritize fledging) with a corresponding linear increase in mass. This pattern is supported by the strong correlations between wing length and mass, and wing and tail lengths. The gain in mass presented in this study (0.046 kg/day) is slightly higher than that presented for this species by Mundy (1982) where he reported a rate of 0.01 kg/day. Mass measurements generally have a lot of intraspecific variation as these can also be affected by factors such as whether the chick had been fed prior to measurement or not. For wing growth rate, Mundy (1982) recorded a mean of 6.8 mm/day which is comparable with this study. It is important to mention that the growth curves presented here are not complete, as measurements at fledging are missing because chicks fledged before they could be measured. Houston (1976) presented a growth curve of a White-backed Vulture at a nest that shows decreasing growth rate after the age of 70 days, therefore it is expected that the growth rate should drop prior to fledging because by then the chicks would have attained maximum wing length. Assuming that the last measurements of bill, head and bill, and tarsus lengths taken before fledging were the maximum measurements (as suggested by the growth curves), then at the age of 80 days the size of the tarsus and bill have reached 90% of their average size at fledging.

Food provisioning rate in this study was expected to increase with the age of the chicks because growing chicks demand an increasing amount of food as they develop. To the contrary there was no correlation between food provisioning rate and age of the chicks. Therefore chick age did not significantly influence food provision rate at White-backed Vulture nests, which is a pattern that would be expected if there was reduced food availability. However, since the chicks showed slightly higher growth rates than those reported previously by Mundy (1982) and were able to fledge successfully, limitation in food availability may not have been an important factor in this case. The food provisioning rate could also be influenced by energy requirements of the chick which tend to vary with age, dropping after 85 days to fledging (Houston 1976, Komen and Brown 1993). In either case the parents may not increase the food provision rate when energy requirements of the chick are low. Houston (1976) reported that Rüppell's Vultures *Gyps rueppellii* did not show a decrease in growth rate when under food stress as they seem not to be able to alter their growth rate as an adaptation to low food availability as seen with other birds. For example, Marabou Stork *Leptoptilos crumeniferus* chicks that hatch late in the season have reduced growth rates, a result associated with low food availability (Monadjem et al. 2010). White-backed Vulture chicks in this study showed normal growth rates similar to Mundy (1982). More research however, is needed to investigate the relationship between food provisioning rate and the age of chicks in order to understand the emerging threat of declining food availability in Africa.

Camera traps present an opportunity to monitor nesting behaviour at multiple nests at the same time that would otherwise require multiple trained data collectors and many hours of field work to collect the same information. The use of camera traps has been reported to be more cost effective than other standard field methods (Rovero and Marshall 2009). Camera traps, however, do come with disadvantages such as the initial costs of buying the equipment, regular disturbance at nesting sites to install cameras and replace batteries, and mechanical failure resulting in data loss. The effects of disturbance can be minimised by keeping nest visits as short as possible and avoiding installing cameras prior to the commencement of incubation. The overall breeding success recorded during this study was low compared to the mean success of previous years (Monadjem 2001, 2004), although breeding success in at least two of the past 15 years have been lower than during the present study (A. Monadjem, unpublished data). This study has shown camera trapping to be a valuable tool that can be effectively used to monitor food provisioning and parental care in White-backed Vulture nests.

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