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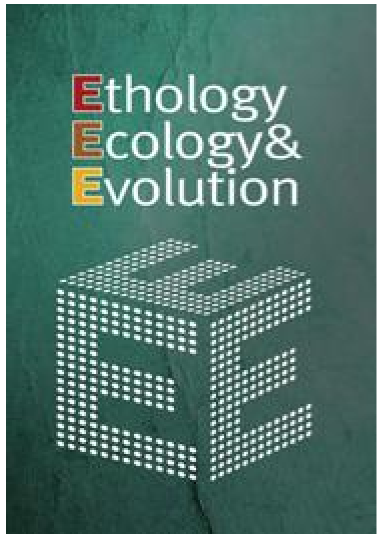

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Short communication

Interactions between Pied crows *Corvus albus* and breeding White-backed vultures *Gyps africanus*

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Abstract

African White-backed vultures *Gyps africanus* are Critically Endangered, mainly due to mortality from poisoning, but the species also exhibits variable breeding productivity that may partially be explained by nest failure due to predation. Pied crows *Corvus albus* have been implicated as nest predators, but because there is no evidence linking Pied crows to low breeding productivity of White-backed vultures, we used a combination of dummy eggs (n = 14) and camera traps on active nests (n = 10), to investigate what species visit White-backed vulture nests (both active and abandoned) and predate on their eggs. We recorded 47 egg predation events, of which 37 (79%) were attributable to Pied crows, while other predators (unidentified large raptors, White-backed vultures and Vervet monkeys) were recorded interacting with eggs five times in total; mobbing by Pied crows of incubating vultures increased the probability vultures would abandon their nest but crows did not eat abandoned eggs as soon as they were available. Further studies are needed across a wider range of vulture breeding areas to contextualise these findings both in terms of breeding productivity and the significant risks of mortality faced by vultures from poisoning and other threats.

INTRODUCTION

Nest failure in birds can be caused by a variety of factors such as infertility (Jamieson & Ryan 2000), egg-shell thinning (Castilla et al. 2010), predation (Feare et al. 2017), and modification to nesting habitat (Evans 2003). For vultures and other long-lived raptors, disturbance by humans (Bamford et al. 2009) can be a important cause of breeding failure (Borello & Borello 2002), Determining the actual cause of low breeding productivity in birds can thus be challenging and, in some cases, important for identifying threats to endangered birds (Hemmings et al. 2012).

White-backed vultures *Gyps africanus* are Critically Endangered (Birdlife International 2016), mainly due to rapid population declines caused by poisoning mortality, where several hundred vulture can be killed at a single event (Murn & Botha 2017), and a variety of other threats such as harvesting for the wildlife trade or electrocution on power lines (Ogada et al. 2016). They also exhibit a variable breeding success across their range, from 50-60% in South Africa to over 80% in East Africa (Mundy et al. 1992). Whilst the major causes of mortality in White-backed vultures have been identified, such as poisoning and harvesting for belief-based use (Ogada et al. 2016), it is still unclear why breeding productivity varies between regions and years.

Near Kimberley in central South Africa, there is a population of approximately 170 breeding pairs of White-backed vultures (Murn et al. 2017) that has been at least partially monitored since the 1960s (Forrester 1967). Within the Kimberley area, some local ecologists and land owners suspect that White-backed vulture nest failure and subsequent low breeding productivity is caused by egg and chick predation, with Pied crows *Corvus albus*, and to a lesser extent, Vervet monkeys *Chlorocebus pygerythrus,* considered the most likely nest predators. Given that Pied crows are well-known as nest predators (Carlson & Hartman 2001; Sensory Ecology 2013a, 2013b), it is possible that they predate on vulture eggs and chicks, and negative interactions between corvids and vultures have been recorded elsewhere (Bertran & Margalida 2005). However, at about 10% of their weight (Hockey et al. 2005), Pied crows are considerably smaller than White-backed vultures and it seems unlikely that Pied crows could force a White-backed vulture from its nest. Regardless, as the Pied crow population in central and southwestern South Africa has grown and expanded over recent decades (Cunningham et al. 2016), speculation has arisen that crows might be negatively affecting White-backed vulture breeding productivity. Despite these concerns, there are no data or published accounts of interactions between nesting White-backed vultures and Pied crows. Speculation cannot inform conservation management decisions and there is a recognised need for research to understand the existence and/or degree of threat posed by Pied crows to other bird species in South Africa (BirdLife South Africa 2012).

Various other predators or nest visitors could be responsible for reduced breeding success in White-backed vultures, including a variety of large raptors, or primates such as Vervet monkeys and Chacma baboons *Papio ursinus* (Thompson et al. 2017). However, information about the impacts of other species on vulture nesting success is limited, and probably driven by the difficulties associated with long-term monitoring of nests and/or detecting nest predators. White-backed vulture nests in savanna settings are loosely aggregated (Murn et al. 2013); often only one nest can be kept under direct observation at a time. Furthermore, the incubation and chick-rearing period usually exceeds 5-6 months (Mundy et al. 1992), which has possibly prevented intensive monitoring of White-backed vulture breeding biology. More recently, remote cameras have been used for long-term nest monitoring and chick development studies (Maphalala & Monadjem 2017), but there have been no remote camera studies aimed at determining causes of nest failure in White-backed vultures, unlike for some other vulture species (see Thompson et al. 2017 for Hooded vultures *Necrosyrtes monachus* and Margalida et al. 2006 for Bearded vulture *Gypaetus barbatus*).

We investigated if Pied crows or other species are relevant to the breeding success of White-backed vultures near Kimberley, South Africa. Our aim was to determine if Pied crows or other species were implicated in nest failure of White-backed vultures in the region. We predicted that disturbance or mobbing of nesting vultures by Pied crows would not cause vultures to leave or abandon their nest. However, we also predicted that Pied crows, as a recognised nest predator (Cunningham et al. 2016), would predate upon unattended eggs.

METHODS

The study was conducted between May–August 2015 at Dronfield Nature Reserve (28.64S, 24.80E) and Mokala National Park (29.17S, 24.32E), both located near Kimberley, South Africa. These two protected areas are approximately 60 km apart and contain the two largest breeding colonies of White-backed vultures in the Kimberley area, with an estimated 75 and 55 breeding pairs at Dronfield and Mokala respectively (Murn et al. 2002, 2017). The habitat at both sites is part of the savanna biome, with a Kimberley thornveld vegetation type (Mucina & Rutherford 2006). The vultures nest in the two most common large tree species in the region: Camel thorn *Vachellia erioloba* and Umbrella thorn *Vachellia tortilis.*

Detecting nest predators

To determine if egg or chick predation was responsible for White-backed vulture nest failure, 10 camera traps (Prostalk© PC4000 5.0 megapixel, with a 60° passive infrared sensor) were deployed at active vulture nests. Cameras were programmed to take photos at 30 min intervals, and also whenever there was movement on the nest via an infrared trigger. The cameras were installed in the nest tree, but not directly in the nest, and were angled to capture visitors to the nest and the surrounding canopy at a distance of 1.5-3 m from the nest edge.

To identify nest predators we also made 14 dummy eggs, similar in size and shape to White-backed vulture eggs and deployed these in two settings. Six dummy eggs were placed in unused (inactive) White-backed vulture nests (mean area = 113 cm^2, mean depth = 50 cm). The other eight dummy eggs were placed in hand-made nests (mean area = 72 cm^2, mean depth = 26 cm) in trees nearby to active vulture nests. Eggs were constructed of polyurethane foam (commonly used in taxidermy) and surrounded by a layer of plasticine (painted white) to record bite and scratch marks. Eggs were attached to the nesting tree with string to prevent any animals from completely removing the egg from the nest; grass lining was used to hide the string.

Any marks on the eggs were photographed and measured to catalogue the impressions made by potential predators. Two nests with dummy eggs were monitored with camera traps to record visitors and also calibrate the marks left on the eggs. Unclear impressions or those not captured by camera were identified using museum specimens (teeth, beak, claw and fingers) from a variety of known regional nest predators.

Assessing nest disturbance

The camera traps on active vulture nests recorded the presence or absence and number of Pied crows from the point the egg was laid until the egg either hatched or was abandoned by the vultures. We defined mobbing or disturbance behaviour as the presence of one or more Pied crows in the nest tree for greater than 1 min.

Analysis

To determine if mobbing or nest disturbance increased the probability of vultures abandoning their nest, we performed a logistic regression with abandoned vs not-abandoned as the response variable, and Pied crow mobbing nest (present vs absent) as the predictor. Next, we assessed whether the frequency of Pied crow visits changed as the breeding season progressed in both the abandoned and not-abandoned categories. We performed a logistic regression with Pied crow mobbing nest (present vs absent) as the response, with number of days since egg was laid as a predictor, interacting with outcome (abandoned vs not-abandoned). Analyses were conducted using R 3.2.3 (R Core Team 2015).

RESULTS

Dummy eggs

Dummy eggs were exposed to potential predation over a combined 456 egg/days. All 14 dummy eggs were predated at least twice; on average 3.6 times (range: 2–6). Of the 47 predation events recorded, 28 were in unused vulture nests and 19 in hand-made nests. Pied crows were the most common nest predator (79%, n = 37), followed by unidentified large raptors (6%, n = 3), White-backed Vultures (2%, n = 1) and Vervet Monkeys (2%, n = 1). Five marks could not be identified (11%, n = 5).

Active nests

On the 10 active nests with camera traps, three eggs were predated. Pied crows were responsible for two of these predation events (Fig. 1A); the final predation event, or its timing in relation to the egg being incubated, was not recorded due to camera trap failure. Eggs were only predated after the nest had been abandoned by the vultures for five, nine, and 10 days. On the nest where the egg was predated five days after abandonment, Pied crows visited the nest each day after the vultures left and viewed the egg for 4 days before eating it on the 5th day.

Pied crows were recorded mobbing eight of the 10 nests under observation. Vultures that abandoned their nests experienced significantly more ($Z = 6.32$, $P < 0.001$) mobbing than on non-abandoned nests (Table 1). The frequency of this mobbing did not change throughout the breeding season across all nests ($Z = 0.04$, $P = 0.97$), or between abandoned and non-abandoned nests ($Z = 0.12$, $P = 0.90$).

Mobbing occupied only a small fraction of the total observation period for each nest (total attendance ranged from 696–1752 hr/nest), and there was high variation in the number of times crows visited nests (Table 1). Often, just one crow would visit the nest, but in some cases, up to nine Pied Crows were observed mobbing one nest at a time (Fig. 1B). Mobbing only occurred during daylight hours (Table 1).

Observations regarding predation and dummy eggs

Two Vervet monkeys were observed through binoculars chasing a vulture from its nest. The vulture flew to an adjacent tree ~ 50 m from the nest, whilst the two monkeys sat in the nest for ~ 5.5 min before departing and joining the rest of the troop. Their activity in the nest was unclear as they were facing away from the observer. Once they were gone, the vulture returned to its nest and resumed incubating. Ten min later the observer climbed the tree to find the egg undamaged, and 20 days later the egg hatched.

White-backed Vultures were observed incubating dummy eggs on three separate occasions at three separate nests (two inactive nests, one hand-made nest). These 'incubation' periods lasted from 18–45 min, with one pair of birds swapping with each other to share incubation duties. Birds were only observed incubating on each dummy egg once.

DISCUSSION

Our results show that Pied crows predated dummy eggs more than any other species and that two of the abandoned eggs under observation were eaten by Pied crows. Although mobbing by Pied crows appeared to increase the probability vultures would abandon their nest, Pied crows did not eat eggs in abandoned nests at the earliest opportunity. We found little or no evidence for the threat of egg and chick predation by large raptors or primates.

The apparent increase in the probability of nest abandonment by vultures due to Pied crow mobbing highlights that population growth of Pied crows may impact White-backed vulture breeding productivity negatively. This disturbance at the nest was unexpected, as White-backed vultures are considerably larger than Pied crows, and we had hypothesised it would be unlikely that White-backed vultures would be intimidated by crows. This is the first evidence to support speculation that Pied crows may affect White-backed vulture breeding productivity. However, given the small sample size, it is important for the results in this study to be expanded – both within the Kimberley area and at other locations where Pied crow densities are different.

Pied crows returning to view the same abandoned egg on 5 consecutive days before opting to eat it may be a type of food caching or it could be that crows actively seek non-viable or abandoned eggs. However this would be unusual as the egg remained unhidden in the same location and could either have been eaten by other nest predators or the vultures could have returned to incubate the egg. We are unaware of reports of Pied crows exhibiting food caching, but it is a common behaviour in other corvid species (Grodzinski & Clayton 2010).

We found no evidence that Vervet monkeys predate White-backed vulture eggs at our study sites around Kimberley. With clear bite marks in a dummy egg and a real egg left undamaged, it is possible the monkey only bit the dummy egg out of curiosity, and they are not actually nest predators of White-backed vultures, unlike other avian species (Patterson et al. 2016).

The interactions of White-backed vultures with dummy eggs, both in terms of clawing at and biting a dummy egg and also ‘incubating’ dummy eggs are intriguing and warrant further research. Infanticide by birds other than the parents has been recorded in colonial breeding raptor species (Steen et al. 2016), but attempted infanticide seems an unlikely reason for a vulture to bite an apparently abandoned egg. Polygamous breeding, however, has been observed in Bearded vultures *Gypaetus barbatus* (Bertran & Margalida 2004) and other raptors (Tingay et al. 2002) and this offers some potential insight into reasons for the ‘incubation’ of dummy eggs.

With White-backed vulture populations in decline, understanding the causes of nesting failure will potentially inform conservation management options. Our findings need to be compared with similar studies in other regions (e.g. Maphalala & Monadjem 2017), and on other large raptor species (e.g. Murn & Holloway 2014), to determine if the threat to breeding White-backed vultures from Pied crows or other nest visitors is high (cf. Thompson et al. 2017). However, if Pied crow mobbing is a cause of White-backed vulture nest abandonment, it is important to understand the implications and severity of this for the demography of vulture populations in the light of continued adult vulture mortality from poisoning, energy infrastructure and a range of other threats.

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PERMISSIONS

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this paper.

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Table 1.

Summary statistics for Pied crow mobbing of nesting White-backed vultures. Values highlighted in grey are from nests abandoned by White-backed vultures, white are non-abandoned nests. The eggs in the two abandoned nests listed at the top of the table were both predated by Pied crows after nest abandonment.

Fig. 1. — (A) A Pied crow eating an abandoned White-backed vulture egg. Egg abandoned 5 days prior to predation. (B) Eight Pied crows mobbing a nesting White-backed vulture. Nest was later abandoned by parent birds and the egg was then predated by Pied crows.

Table 1.

Summary statistics for Pied crow mobbing of nesting White-backed vultures. Values highlighted in grey are from nests abandoned by White-backed vultures, white are non-abandoned nests. The eggs in the two abandoned nests listed at the top of the table were both predated by Pied crows after nest abandonment.

Period nest was under observation (days)	Total time crows present at the nest (hr)	Time crows present at nest per day – column 2 divide column 1 (min)	Number of times a crow visited the nest (N)	Mean number of crows ± standard deviation (N)	Mobbing time frame (hh:mm)
60	2.00	2.00	12	2.16 ± 1.93	06:40–15:45
32	0.17	0.32	2	1 ± 0	09:00–11:20
28	0	0	0	–	–
60	0.50	0.50	5	1.37 ± 0.52	07:20–11:20
60	0.08	0.08	1	1 ± 0	08:10–08:10
60	0	0	0	–	–
60	0.08	0.08	1	1 ± 0	08:45–08:45
55	0.17	0.18	1	1 ± 0	09:25–09:30
40	0.08	0.12	1	1 ± 0	10:25–10:25
29	0.25	0.52	3	1 ± 0	08:40–12:05

(A) A Pied crow eating an abandoned White-backed vulture egg. Egg abandoned 5 days prior to predation. (B) Eight Pied crows mobbing a nesting White-backed vulture. Nest was later abandoned by parent birds and the egg was then predated by Pied crows.

903x1354mm (72 x 72 DPI)