

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

Article

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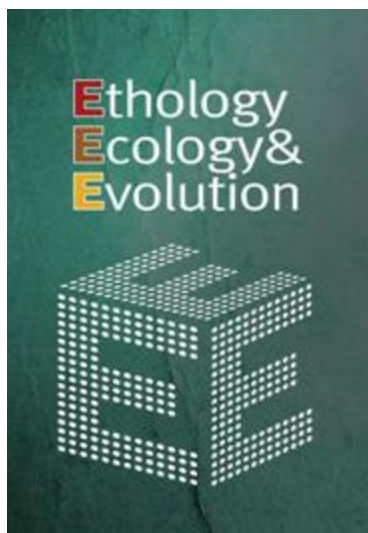
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**Interactions between Pied crows *Corvus albus* and breeding
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9 3 **Interactions between Pied crows *Corvus albus* and breeding White-**
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11 **backed vultures *Gyps africanus***
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8 17 **Abstract**
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10 18 African White-backed vultures *Gyps africanus* are Critically Endangered, mainly due to mortality
11 19 from poisoning, but the species also exhibits variable breeding productivity that may partially be
12 20 explained by nest failure due to predation. Pied crows *Corvus albus* have been implicated as nest
13 21 predators, but because there is no evidence linking Pied crows to low breeding productivity of
14 22 White-backed vultures, we used a combination of dummy eggs (n = 14) and camera traps on active
15 23 nests (n = 10), to investigate what species visit White-backed vulture nests (both active and
16 24 abandoned) and predate on their eggs. We recorded 47 egg predation events, of which 37 (79%)
17 25 were attributable to Pied crows, while other predators (unidentified large raptors, White-backed
18 26 vultures and Vervet monkeys) were recorded interacting with eggs five times in total; mobbing by
19 27 Pied crows of incubating vultures increased the probability vultures would abandon their nest but
20 28 crows did not eat abandoned eggs as soon as they were available. Further studies are needed
21 29 across a wider range of vulture breeding areas to contextualise these findings both in terms of
22 30 breeding productivity and the significant risks of mortality faced by vultures from poisoning and other
23 31 threats.
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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 an 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

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3 61 decades (Cunningham et al. 2016), speculation has arisen that crows might be negatively affecting
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5 62 White-backed vulture breeding productivity. Despite these concerns, there are no data or published
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7 63 accounts of interactions between nesting White-backed vultures and Pied crows. Speculation
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9 64 cannot inform conservation management decisions and there is a recognised need for research to
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11 65 understand the existence and/or degree of threat posed by Pied crows to other bird species in
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14 66 South Africa (BirdLife South Africa 2012).

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16 67 Various other predators or nest visitors could be responsible for reduced breeding success in White-
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18 68 backed vultures, including a variety of large raptors, or primates such as Vervet monkeys and
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20 69 Chacma baboons *Papio ursinus* (Thompson et al. 2017). However, information about the impacts of
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22 70 other species on vulture nesting success is limited, and probably driven by the difficulties associated
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24 71 with long-term monitoring of nests and/or detecting nest predators. White-backed vulture nests in
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26 72 savanna settings are loosely aggregated (Murn et al. 2013); often only one nest can be kept under
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28 73 direct observation at a time. Furthermore, the incubation and chick-rearing period usually exceeds
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30 74 5-6 months (Mundy et al. 1992), which has possibly prevented intensive monitoring of White-backed
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32 75 vulture breeding biology. More recently, remote cameras have been used for long-term nest
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34 76 monitoring and chick development studies (Maphalala & Monadjem 2017), but there have been no
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36 77 remote camera studies aimed at determining causes of nest failure in White-backed vultures, unlike
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38 78 for some other vulture species (see Thompson et al. 2017 for Hooded vultures *Necrosyrtes*
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40 79 *monachus* and Margalida et al. 2006 for Bearded vulture *Gypaetus barbatus*).

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42 80 We investigated if Pied crows or other species are relevant to the breeding success of White-
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44 81 backed vultures near Kimberley, South Africa. Our aim was to determine if Pied crows or other
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46 82 species were implicated in nest failure of White-backed vultures in the region. We predicted that
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48 83 disturbance or mobbing of nesting vultures by Pied crows would not cause vultures to leave or
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50 84 abandon their nest. However, we also predicted that Pied crows, as a recognised nest predator
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52 85 (Cunningham et al. 2016), would predate upon unattended eggs.
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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 cm², mean depth = 50 cm). The other eight dummy eggs were placed in hand-made nests (mean area = 72 cm², 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

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3 113 visitors and also calibrate the marks left on the eggs. Unclear impressions or those not captured by
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5 114 camera were identified using museum specimens (teeth, beak, claw and fingers) from a variety of
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7 115 known regional nest predators.
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10 116 11 12 13 117 *Assessing nest disturbance*

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16 118 The camera traps on active vulture nests recorded the presence or absence and number of Pied
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18 119 crows from the point the egg was laid until the egg either hatched or was abandoned by the
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20 120 vultures. We defined mobbing or disturbance behaviour as the presence of one or more Pied crows
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22 121 in the nest tree for greater than 1 min.
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26 27 28 123 *Analysis*

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30 124 To determine if mobbing or nest disturbance increased the probability of vultures abandoning their
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32 125 nest, we performed a logistic regression with abandoned vs not-abandoned as the response
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34 126 variable, and Pied crow mobbing nest (present vs absent) as the predictor. Next, we assessed
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36 127 whether the frequency of Pied crow visits changed as the breeding season progressed in both the
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38 128 abandoned and not-abandoned categories. We performed a logistic regression with Pied crow
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40 129 mobbing nest (present vs absent) as the response, with number of days since egg was laid as a
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42 130 predictor, interacting with outcome (abandoned vs not-abandoned). Analyses were conducted using
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44 131 R 3.2.3 (R Core Team 2015).
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48 132 RESULTS

49 50 51 133 *Dummy eggs*

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54 134 Dummy eggs were exposed to potential predation over a combined 456 egg/days. All 14 dummy
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56 135 eggs were predated at least twice; on average 3.6 times (range: 2–6). Of the 47 predation events
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58 136 recorded, 28 were in unused vulture nests and 19 in hand-made nests. Pied crows were the most
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60 137 common nest predator (79%, n = 37), followed by unidentified large raptors (6%, n = 3), White-

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3 138 backed Vultures (2%, n = 1) and Vervet Monkeys (2%, n = 1). Five marks could not be identified
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5 139 (11%, n = 5).
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8 140 *Active nests*

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11 141 On the 10 active nests with camera traps, three eggs were predated. Pied crows were responsible
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13 142 for two of these predation events (Fig. 1A); the final predation event, or its timing in relation to the
14
15 143 egg being incubated, was not recorded due to camera trap failure. Eggs were only predated after
16
17 144 the nest had been abandoned by the vultures for five, nine, and 10 days. On the nest where the egg
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19 145 was predated five days after abandonment, Pied crows visited the nest each day after the vultures
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21 146 left and viewed the egg for 4 days before eating it on the 5th day.
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23

24 147 Pied crows were recorded mobbing eight of the 10 nests under observation. Vultures that
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26 148 abandoned their nests experienced significantly more ($Z = 6.32$, $P < 0.001$) mobbing than on non-
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28 149 abandoned nests (Table 1). The frequency of this mobbing did not change throughout the breeding
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30 150 season across all nests ($Z = 0.04$, $P = 0.97$), or between abandoned and non-abandoned nests ($Z =$
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32 151 0.12 , $P = 0.90$).
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35 152 Mobbing occupied only a small fraction of the total observation period for each nest (total
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37 153 attendance ranged from 696–1752 hr/nest), and there was high variation in the number of times
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39 154 crows visited nests (Table 1). Often, just one crow would visit the nest, but in some cases, up to
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41 155 nine Pied Crows were observed mobbing one nest at a time (Fig. 1B). Mobbing only occurred
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43 156 during daylight hours (Table 1).
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49 158 *Observations regarding predation and dummy eggs*

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52 159 Two Vervet monkeys were observed through binoculars chasing a vulture from its nest. The vulture
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54 160 flew to an adjacent tree ~ 50 m from the nest, whilst the two monkeys sat in the nest for ~ 5.5 min
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56 161 before departing and joining the rest of the troop. Their activity in the nest was unclear as they were
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58 162 facing away from the observer. Once they were gone, the vulture returned to its nest and resumed
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3 163 incubating. Ten min later the observer climbed the tree to find the egg undamaged, and 20 days
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5 164 later the egg hatched.
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8 165 White-backed Vultures were observed incubating dummy eggs on three separate occasions at three
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10 166 separate nests (two inactive nests, one hand-made nest). These 'incubation' periods lasted from
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12 167 18–45 min, with one pair of birds swapping with each other to share incubation duties. Birds were
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14 168 only observed incubating on each dummy egg once.
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17 169 DISCUSSION

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20 170 Our results show that Pied crows predated dummy eggs more than any other species and that two
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22 171 of the abandoned eggs under observation were eaten by Pied crows. Although mobbing by Pied
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24 172 crows appeared to increase the probability vultures would abandon their nest, Pied crows did not
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26 173 eat eggs in abandoned nests at the earliest opportunity. We found little or no evidence for the threat
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28 174 of egg and chick predation by large raptors or primates.
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31 175 The apparent increase in the probability of nest abandonment by vultures due to Pied crow mobbing
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33 176 highlights that population growth of Pied crows may impact White-backed vulture breeding
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35 177 productivity negatively. This disturbance at the nest was unexpected, as White-backed vultures are
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37 178 considerably larger than Pied crows, and we had hypothesised it would be unlikely that White-
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39 179 backed vultures would be intimidated by crows. This is the first evidence to support speculation that
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41 180 Pied crows may affect White-backed vulture breeding productivity. However, given the small sample
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43 181 size, it is important for the results in this study to be expanded – both within the Kimberley area and
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45 182 at other locations where Pied crow densities are different.
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49 183 Pied crows returning to view the same abandoned egg on 5 consecutive days before opting to eat it
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51 184 may be a type of food caching or it could be that crows actively seek non-viable or abandoned eggs.
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53 185 However this would be unusual as the egg remained unhidden in the same location and could either
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55 186 have been eaten by other nest predators or the vultures could have returned to incubate the egg.
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57 187 We are unaware of reports of Pied crows exhibiting food caching, but it is a common behaviour in
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59 188 other corvid species (Grodzinski & Clayton 2010).
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3 189 We found no evidence that Vervet monkeys predate White-backed vulture eggs at our study sites

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5 190 around Kimberley. With clear bite marks in a dummy egg and a real egg left undamaged, it is

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7 191 possible the monkey only bit the dummy egg out of curiosity, and they are not actually nest

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9 192 predators of White-backed vultures, unlike other avian species (Patterson et al. 2016).

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12 193 The interactions of White-backed vultures with dummy eggs, both in terms of clawing at and biting a

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14 194 dummy egg and also 'incubating' dummy eggs are intriguing and warrant further research.

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16 195 Infanticide by birds other than the parents has been recorded in colonial breeding raptor species

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18 196 (Steen et al. 2016), but attempted infanticide seems an unlikely reason for a vulture to bite an

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20 197 apparently abandoned egg. Polygamous breeding, however, has been observed in Bearded

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22 198 vultures *Gypaetus barbatus* (Bertran & Margalida 2004) and other raptors (Tingay et al. 2002) and

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24 199 this offers some potential insight into reasons for the 'incubation' of dummy eggs.

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27 200 With White-backed vulture populations in decline, understanding the causes of nesting failure will

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29 201 potentially inform conservation management options. Our findings need to be compared with similar

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31 202 studies in other regions (e.g. Maphalala & Monadjem 2017), and on other large raptor species (e.g.

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33 203 Murn & Holloway 2014), to determine if the threat to breeding White-backed vultures from Pied

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35 204 crows or other nest visitors is high (cf. Thompson et al. 2017). However, if Pied crow mobbing is a

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37 205 cause of White-backed vulture nest abandonment, it is important to understand the implications and

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39 206 severity of this for the demography of vulture populations in the light of continued adult vulture

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41 207 mortality from poisoning, energy infrastructure and a range of other threats.

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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.

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 \pm standard deviation (N)	Mobbing time frame (hh:mm)
60	2.00	2.00	12	2.16 \pm 1.93	06:40–15:45
32	0.17	0.32	2	1 \pm 0	09:00–11:20
28	0	0	0	–	–
60	0.50	0.50	5	1.37 \pm 0.52	07:20–11:20
60	0.08	0.08	1	1 \pm 0	08:10–08:10
60	0	0	0	–	–
60	0.08	0.08	1	1 \pm 0	08:45–08:45
55	0.17	0.18	1	1 \pm 0	09:25–09:30
40	0.08	0.12	1	1 \pm 0	10:25–10:25
29	0.25	0.52	3	1 \pm 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)