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Quantifying the spatial distribution and trends of supplementary feeding sites in South Africa and their potential contribution to vulture energetic requirements.

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Abstract

Old world vultures are the most threatened group of raptors globally. Supplementary feeding sites (SFS) are a popular conservation tool, widely used to assist vulture populations. Despite their popularity, the impact of SFS on vultures remains largely unstudied. A lack of knowledge on the number, distribution and management of SFS is a key factor hindering such research. In this study, we compile records of SFS in South Africa and conduct questionnaires with SFS managers to characterise SFS. We identify 143 currently active SFS. Our data suggest that SFS numbers have been stable over the last decade. The average provisioning rate for all SFS was 64.6 kg/day. Overall SFS provide an estimated 3301 tonnes of food to scavengers each year, the equivalent of 83% of the energetic needs of all vultures in the region. This contribution was highly skewed, however, with just 17% of active SFS sites providing 69% of all food. Furthermore, these resources were not equally distributed, with SFS in Limpopo, North West and Kwazulu-Natal provinces providing 83% of the total meat provisioned. The three most common meat types provided at SFS were beef (39%), pork (33%) and game (19%). Worryingly, we found that 68% and 28% of SFS managers were unaware of

the potential harmful effects of lead and veterinary drugs, respectively, which highlights potential poisoning risks associated with SFS. Examining exposure to SFS by different vulture species, we found that whilst SFS are accessible across the distribution range of vultures with large home ranges (e.g. African white-backed and Cape vultures), those species with smaller home ranges have relatively poor accessibility. With this study we demonstrate the potential importance, but also associated risks, of SFS to vultures in South Africa, and provide the information-base to assess the impacts of this popular but as yet largely un-assessed conservation tool.

Keywords: vulture restaurant, anthropogenic food, conservation management, scavengers.

Introduction

The decline of biodiversity often requires the implementation of intensive management actions (Butchart et al., 2010; Barnosky et al., 2011). Because of the inherent uncertainty in how biological systems will react to conservation interventions (Keith et al., 2011), some management actions can cause unintended negative effects on target species or ecosystems (Ainara Cortés-Avizanda et al., 2009; Wittmer, Elbroch, & Marshall, 2013). Validating the beneficial outcome of such interventions is thus a crucial role of conservation science. To facilitate such inquiry, responsible management should entail continuous monitoring and assessment. This is the only way in which to ensure that limited conservation resources are not wasted on ineffective or detrimental interventions (Santangeli & Sutherland, 2017).

Food supplementation is an intensive management intervention often meant to help threatened species. While its effects in a conservation context are in many cases unknown, unintended negative ecological effects of food supplementation have been reported (Robb et al., 2008; Milner et al., 2014). These include changes in social and movement behaviour (Duriez, Herman, & Sarrazin, 2012; Jones et al., 2014; Fluhr et al., 2017), predation and selection pressures (Schmidt & Hoi, 2002; Ainara Cortés-Avizanda et al., 2009), interspecific relationships (Carrete et al., 2010; Cortés-Avizanda et al., 2012) sex ratios and reproductive performance (Clout, Elliott, & Robertson, 2002; Carrete, Donázar, & Margalida, 2006) and various health factors (Blanco, Lemus, & García-Montijano, 2011; Sorensen, van Beest, & Brook, 2014).

Almost seventy percent of old-world vulture species are threatened with extinction (IUCN, 2019), the most rapid population declines occurring in the vulture-rich regions of Asia and Africa (Ogada et al., 2016). Over the last decade, the unnatural and accelerated mortality rates of vultures across Africa have led to the International Union for Conservation of Nature (IUCN) uplisting seven out of ten of the continent's vulture species to Critically Endangered and Endangered (Amar et al., 2018). While this can be attributed to various threats (Anderson, Maritz, & Oosthuysen, 1999; Boshoff et al., 2011; McClure et al., 2018), the most prevalent of these is poisoning. This risk of poisoning include: direct poisoning - for traditional belief-based use of vulture parts (Mckean et al., 2013), or "sentinel poisoning", whereby poachers target vultures as they provide rangers with a clear sign of poaching

events (Ogada et al., 2016), and indirect secondary poisoning - where vultures are the unintended victims of the poisoning of so-called problem carnivores (Santangeli et al., 2016). Similarly, vultures may be poisoned by feeding on livestock treated with veterinary drugs (Gilbert et al. 2002; Oaks et al. 2004), or lead contaminated carcasses (Bounas et al. 2016; Garbett et al. 2018), which may even lead to catastrophic population level impacts (Green et al., 2004).

The high mobility and wide ranging behaviours of vultures make conserving them challenging because conventional conservation measures, such as protected areas, may be insufficient (Santangeli et al., 2019). In South Africa, there has been a strong emphasis on providing additional food through supplementary feeding sites (SFS; often also referred to as “vulture restaurants”, Cortés-Avizanda et al., 2016). These measures have been implemented because providing such food is typically assumed to reduce poisoning risk (Gilbert et al., 2007), with some evidence indicating it can also increase breeding success and survival (González et al., 2006; Oro et al., 2008). However, such effects are not ubiquitous and in some cases SFS show no effects (Krüger, Simmons, & Amar, 2015; Oppel et al., 2016a). SFS therefore remain a debated conservation tool (Oppel et al., 2016b).

Anderson and colleagues (2005) previously estimated that there were around 140-145 active SFS in South Africa, with an annual increase of 9% per year. The majority of SFS are established informally by land managers, particularly as an easy and inexpensive form of carcass disposal (Mundy et al., 1992; Piper, 2004b). Therefore, many SFS are potentially operated without following best-practice guidelines (Piper, 2004a). Essential information on the number, status (active - providing food, or closed), location and provisioning rate of SFS is lacking and not collated into a systematic centralised database. This hinders investigations on the effects of SFS on vultures in Africa (e.g., Kane et al., 2014), which is essential to understand the conservation outcomes of SFS. The first step in quantifying the effectiveness of SFS is thus to systematically gather this information.

Here, we aim to fill this knowledge gap in South Africa and lay the basis for future studies on this common, yet un-assessed conservation tool. Specifically, we aim to i) determine the current and historical number and distribution of active SFS in South Africa; ii) quantify the amount and type of food resources being provisioned at these SFS; iii) estimate the contribution of SFS resources towards filling the energetic needs of the different vulture species based on their potential access to SFS.

Methods

Ethics statement

This study was approved by the Faculty of Science Research Ethics Committee at the University of Cape Town (Approval code: FSREC 83 – 2017). Participants provided informed verbal consent, as approved by the ethics committee.

Supplementary feeding site data

We used existing datasets on SFS from three organisations in South Africa which are extensively involved in vulture conservation (VulPro, The Endangered Wildlife Trust and Ezemvelo KwaZulu-Natal Wildlife). These datasets were out-dated to various extents and the information they contained had not been verified during recent years. We consolidated all three databases.

We conducted a survey with the managers or affiliated persons of each SFS. The survey was conducted by a single interviewer (CWB) over the telephone or email, using an open-ended questionnaire (see Supplementary Material). Surveys were conducted between November 2017 and October 2018. Respondents were asked to provide a range of information regarding their SFS, most notably coordinates of the site, the status of the SFS (whether the site was active, i.e. provisioning food, or closed and no longer provisioning) their provisioning rates (tonnes per year), type of carcasses used, their date of establishment and closure and reasons for establishment and closure. SFS managers were also presented with a multiple-choice question regarding whether they believed that lead from spent ammunition or veterinary drugs present in carcasses could have any potential harmful effects on vultures.

Provisioning rate calculations

Respondents were asked to specify, as accurately as possible, the type and quantity of food (a combination of whole carcasses and offal) that they provide at their SFS within a given time unit. When respondents provided weights per carcass or specified the amount of offal in kilograms (the parts of an animal carcass that is discarded after butchering or dressing), these amounts were used. In cases where respondents provided a quantity range, the mid-point of this range was used to calculate provisioning rate. However, when livestock carcass weights were not provided but only the numbers of carcasses, we used the body mass of animals from the literature averaged across breeds within a specific livestock type (Cloete & De Villiers, 1987; Cloete et al., 2000; Wells & Krecek, 2001; Sheridan, Ferreira, & Hoffman, 2003; Scholtz, 2010; Snyman, 2014a, 2014b, 2014c, 2014d, 2014e; Andrew Tucker unpubl. data).

To determine provisioning rate of game animals, the average mass of game species was derived from the 2016 South African hunting statistics (available from the Department of Environmental Affairs) and published weights (Stuart & Stuart, 2015). When respondents indicated an amount provisioned during the hunting season, we assumed that this was provided over the average winter hunting season, which is three months in duration.

To calculate the amount of offal provided we used averaged dress out percentages (ratio of slaughtered and vicerated carcass to live weight) from the literature for each animal group. This was only needed for the game and pork category as all other livestock offal amounts were indicated in weights. South African dress out percentage for a range of ungulate species falls within a 52-61% of body weight (Von La Chevallerie 1970; Hoffman 2000; Van Zyl & Ferreira 2004; Hoffman & Wiklund 2006; Hoffman et al. 2009; Swanepoel et

al. 2016). Offal thus accounts for between 39-48% of live weight. We used the conservative measure of 40% of live weight for our calculations of offal weight as some offal is commonly used for human consumption. Dressing weights for domestic pigs were between 72-84% (Latorre et al. 2009; Warriss et al. 1990; Boler et al. 2012; Virgili et al. 2003), thus for pigs we used 20% as percentage offal of live weight. QGIS was used for all spatial analyses (QGIS, 2019).

Calculation of vulture energetic needs

To contextualise the total amount of food being provided by SFS, we calculated the total annual food requirements of all vultures in the South Africa, Lesotho and eSwatini region (Appendix 1). We used adult vulture population estimates, indications of the proportion of the population that are adults, and daily food requirements from the literature to do these calculations (Appendix 1). In addition to the SFS within South Africa, provisioning rates from two verified SFS in Lesotho and two in eSwatini were included in this calculation. The species evaluated included the IUCN Critically Endangered African white-backed vulture, *Gyps africanus*, Endangered Cape vulture, *Gyps corprotheres*, Endangered lappet-faced vulture, *Torgos tracheliotos*, Near Threatened bearded vulture, *Gypaetus barbatus*, Critically Endangered hooded vulture, *Necrosyrtes monachus*, and Critically Endangered white-headed vulture, *Trigonoceps occipitalis* (IUCN, 2019).

Coverage of species range by SFS

Adult vultures often have smaller home ranges than non-adults and thus their access to SFS is more restricted (eg. Krüger, Reid, & Amar, 2014). For this reason, we focussed this analysis on adults only. We quantified the proportion of each species' distribution range that is accessible to SFS in the following way. First, we collated home range estimates for each species from the literature (Krüger, Reid, & Amar, 2014; Kane et al., 2016; Garbett, 2018; Reading et al., 2019). Such estimates were unavailable for adult African white-backed vultures, but as evidence suggests they display similar movement behaviour as lappet-faced vultures (Spiegel, Getz, & Nathan, 2013), we thus used lappet-faced vulture estimates as a proxy. The average across all species was used for white-headed vultures for which data were also unavailable. Assuming uniform circular home ranges, we converted these species-specific home range estimates to minimum and maximum buffers for each species. We used 95% Kernel Density Estimates (KDE), 90% in the case of bearded vultures, for the calculation of the maximum buffer radiuses and 50% KDE for the minimum buffer radius of each species. . These species-specific radiuses were then used to create buffers around each active SFS in the region. Finally, we calculated the proportion of each vulture species' range covered by the minimum and maximum buffer surrounding SFS in the region. This yielded a minimum and maximum proportion of species range coverage by SFS. We repeated the above analyses using only SFS with high provisioning rates (>40 kg/day).

Results

We were able to contact 92.4% of the SFS for which we had working contact details. The remainder either refrained from responding to all attempts at communication or had closed so long ago that no relevant respondent could be found. Of those we did contact, 72.4 % participated in the study beyond just simple verification of the status of their SFS. Among verified and currently active SFS, we had a response rate of 94.3%.

State of SFS in South Africa

We verified the status of 232 SFS records in South Africa, including 25 new sites (i.e., not present in the three original datasets) that were mentioned by respondents and verified on an ad-hoc basis. Among verified SFS, 143 were active (Figure 1), and 89 were closed. Ninety entries remained unverified, due to out-dated contact information. Given the age of the databases and their entries, these were assumed to be closed.

Trend and motivations of SFS establishment

We gathered information on establishment and closure dates of 104 currently active and 39 closed SFS. The earliest reported establishment date was 1933. From 1975 numbers of active SFS increased sharply, but have remained relatively constant since around 2009 (Figure 3).

The main motivation for establishing an SFS was for conserving vultures (65% of 159 total responses) and for the cleaning benefits vultures provide (26%). Other reasons were the personal pleasure of running an SFS (12%) and ecotourism (11%).

Reasons for closing SFS were: managers moving away (22% out of 55 responses), low vulture visitation rates (13%), relocation of SFS (11%), carcass contamination concerns and lack of control regarding dumping by general public (11%), lack of carcasses for provisioning (7%), and occurrence of powerline mortalities (7%).

Provisioning Rates

We obtained information on provisioning rates from 132 of the 143 active SFS. Of these, 24 provided both livestock and game, 82 provided livestock only and 26 provided game only. Eight SFS that only provided game, indicated that their SFS was solely active during the hunting season. There was high variability in provisioning rate among SFS, with a mean \pm S.D. of 23.58 t/y \pm 38.84 (range: 0.32 - 208.57 t/y), equivalent to 64.61 kg/day \pm 106.42. Across all SFS for which data was collected, we estimated that 3113 tonnes of food are provided each year. If extrapolated across sites with unknown provisioning rates, using the average of similar types of sites in the same province (or across the entire country in the case of Nature and Game Reserves), then 3301 tonnes of food are provided across all known active SFS.

The contribution of food provisioned was highly skewed, with just 17% of active sites providing 69% of reported total annual provisioned food (Appendix 2). Sites with highest

provisioning rates are generally affiliated with intensive livestock farms, abattoirs or Non-Governmental Organisations (NGO) who source carcasses from such operations. Sites that provided little food annually are represented more often by small-scale livestock farms. We report high variation in resource contribution by SFS across South Africa, with Limpopo, KwaZulu-Natal and North West provinces providing the majority of food resources (Figure 2). Across South Africa, most of the total food provisioned consisted of beef (39.2%), pork (33.3%) and game (19.4%, Appendix 3). Less common meat sources included sheep (3.6%), horses/donkeys (2.2%), chicken (1.0%) and goat (0.2%).

Potential energetic contribution of SFS

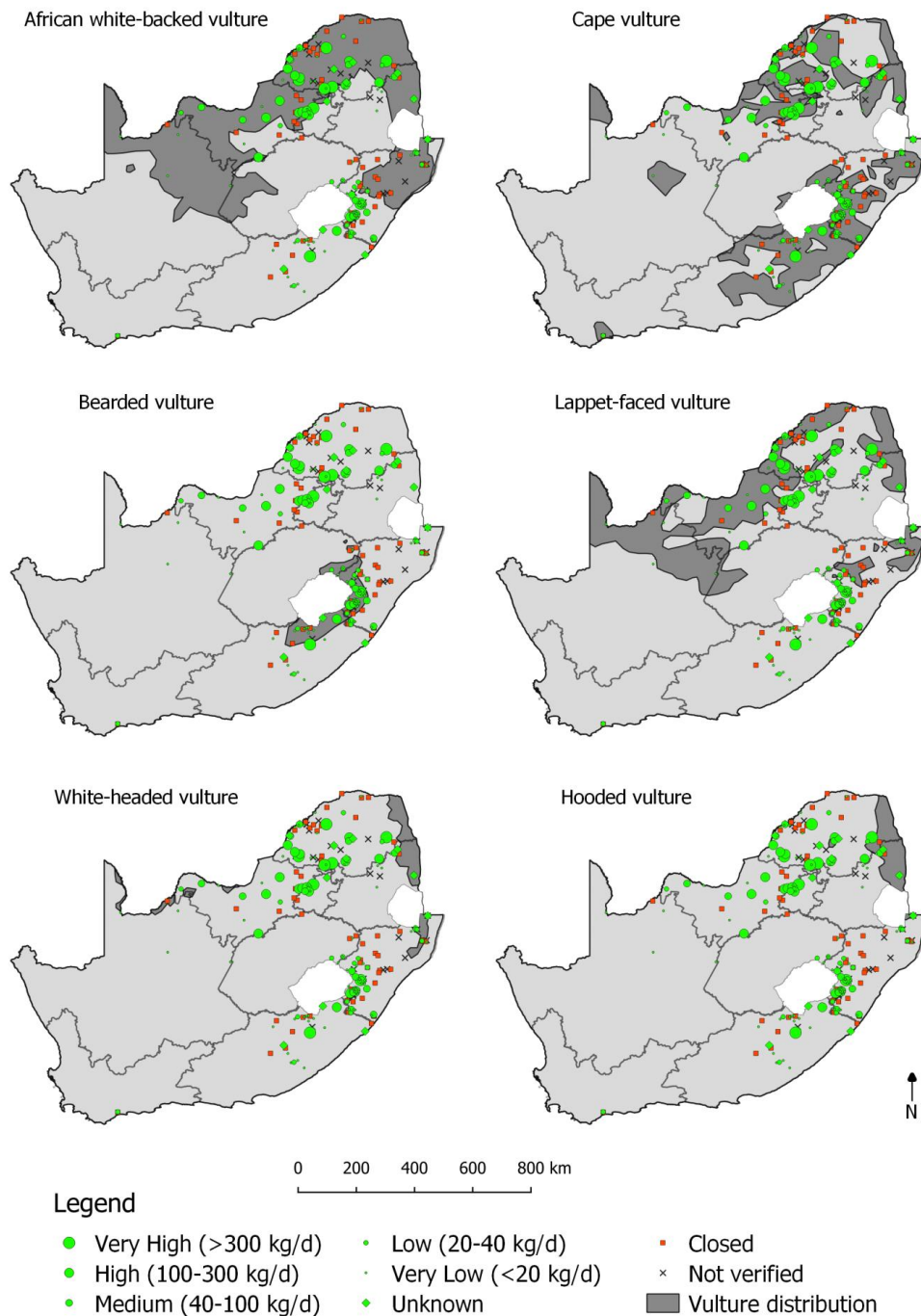
We estimated that the extrapolated total provisioning rate of 3301 t/y, plus 16 t/y provided at SFS in eSwatini and Lesotho, is enough to potentially fulfil about 83 % of the annual food requirements for vultures in South Africa.

Food safety

Out of 111 respondents answering the question on the health risks posed to vultures from providing contaminated food, 32% of managers believed that lead from spent ammunition could be dangerous to vultures, 35% were not sure and 32% were convinced otherwise. For veterinary drugs, 72% believed that they could have harmful effects, 20% were unsure and 8% were convinced otherwise.

Vulture range coverage by SFS

The South African range of lappet-faced vultures, African white-backed vultures and Cape vultures had highest accessibility to SFS, with 100% of their range being covered by any SFS, and 79% to 81% when considering only SFS providing more than 40 kg/d (Table 1). Conversely, hooded and bearded vultures had the lowest SFS range coverage (Table 1).

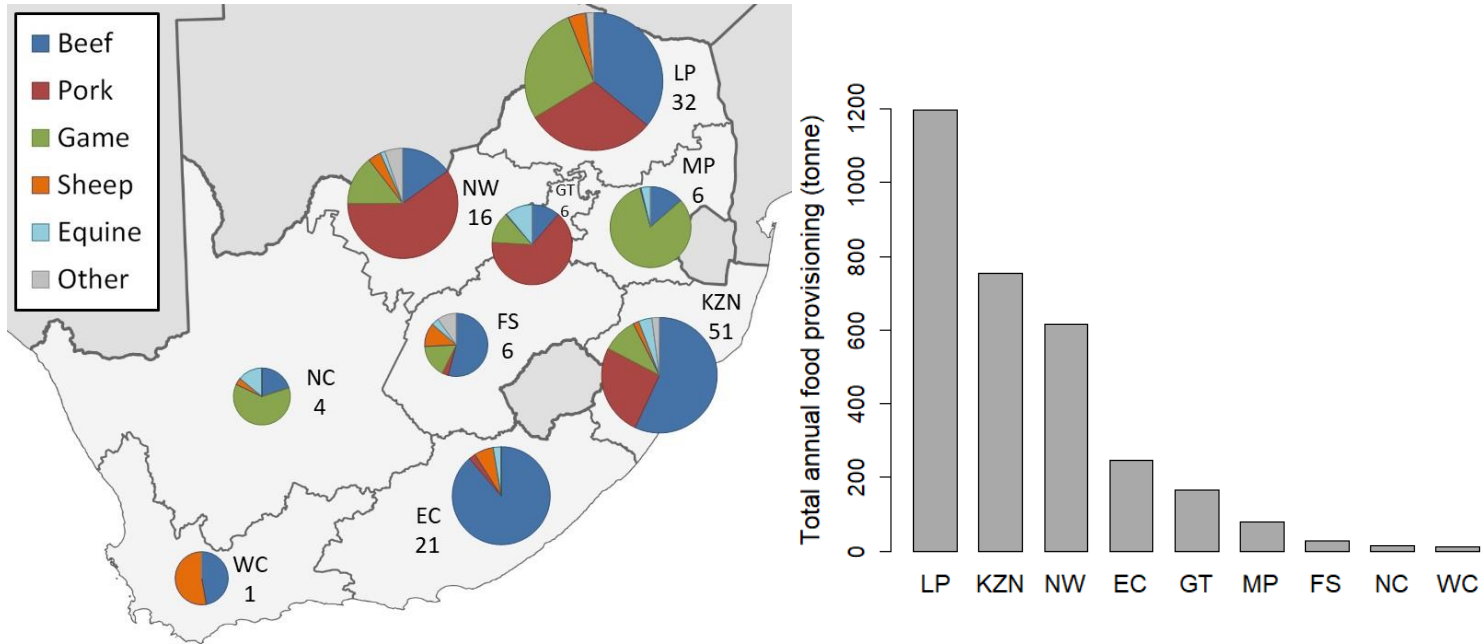


1

2 **Figure 1:** The distribution and status of vulture supplementary feeding sites in South Africa
 3 as verified by the present study. Active (green), closed (red) and unverified (black cross)
 4 supplementary feeding sites are indicated. The average daily food provisioning rate category
 5 of active sites is indicated by the size of the green circles, green diamonds indicate active
 6 supplementary feeding but with unknown provisioning rates. The distribution of each of six
 7 vulture species occurring in South Africa is shown in dark grey (data obtained from BirdLife
 8 International and NatureServe 2015).

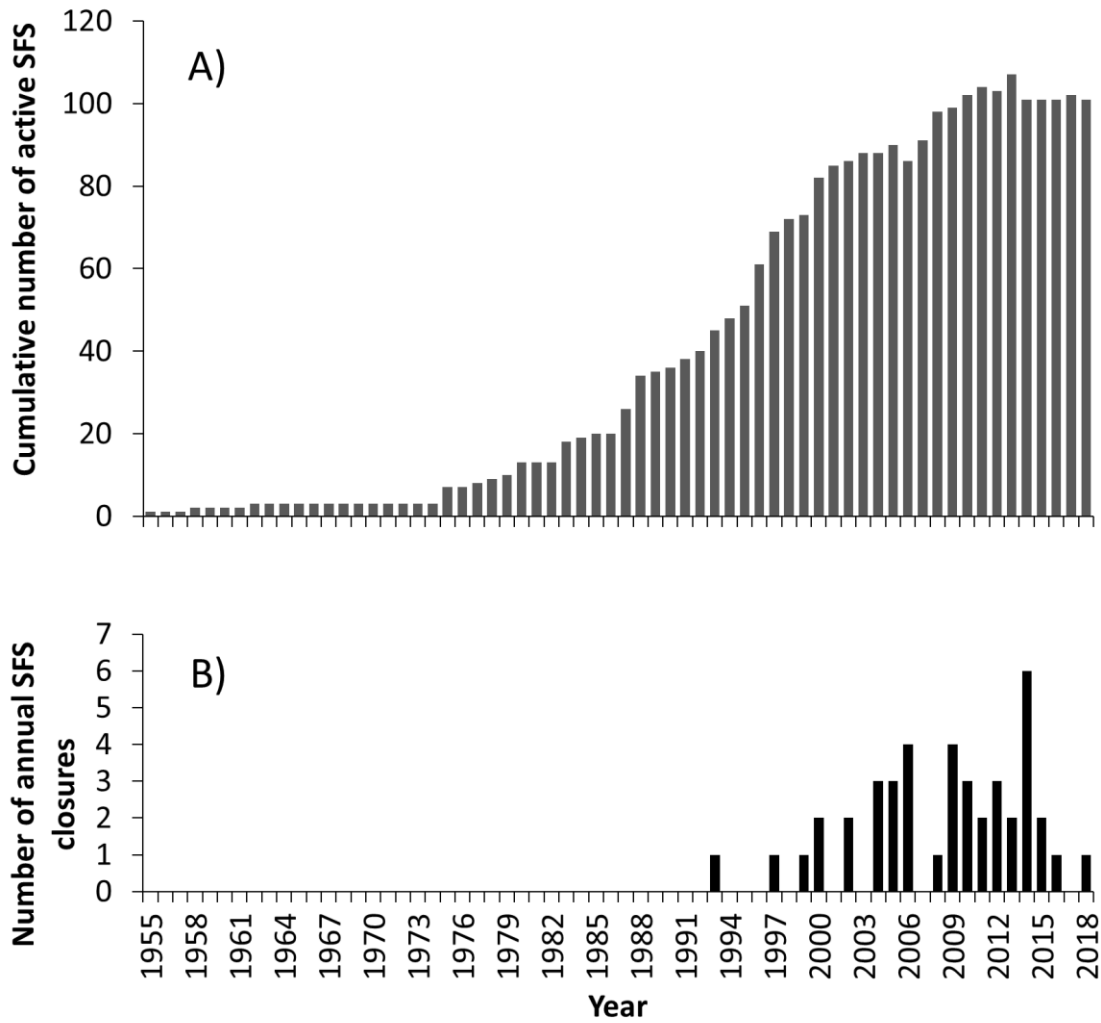
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12 **Figure 2:** Proportional contribution of each meat type to the total food provisioned at supplementary feeding sites in each province in South
13 Africa (shown by the pie charts within each region in the map). The size of each pie chart is proportional to the total amount of food
14 provisioned in each province per year (log transformed to ease visualisation). Numbers below the name of each province in the map indicate
15 the number of active supplementary feeding sites in that province. The total amount of food provided at supplementary feeding sites in each
16 province in tonnes per year is reported in the histogram to the right. (LP = Limpopo, KZN = KwaZulu Natal, NW = North West, EC = Eastern
17 Cape, GT = Gauteng, MP = Mpumalanga, FS = Free State, NC = Northern Cape, WC = Western Cape).



19

20 **Figure 3:** A) Cumulative number of active SFS over time in South Africa, and B) the number
21 of annual SFS closures. This is based on information of opening and closing dates obtained
22 from 155 SFS. We start the timeline at 1955 for brevity, because between 1933 and 1955
23 only a single SFS was reported as active. Sites that did not provide this information were
24 excluded here.

25

26

27

28 **Table 1:** The percentage area of vulture species' South African distribution range that is within adult vulture maximum (based on 95% Kernel Density Estimates, except for bearded vultures
29 which is based on 90% Kernel Density Estimates) and minimum (based on 50% Kernel Density Estimates) home range distances from SFS and SFS with higher provisioning rates respectively.

Species	Maximum buffer radius (km)	Minimum buffer radius (km)	South African distribution range (km ²)	All SFS		Higher provisioning rate SFS (>40 kg/d)	
				Percentage area within maximum home range distance (%)	Percentage area within minimum home range distance (%)	Percentage area within maximum home range distance (%)	Percentage area within minimum home range distance (%)
Lappet-faced vulture	249	94	243927	100	84	79	45
African white-backed vulture	249	94	399801	100	81	81	46
Cape vulture	187	56	285533	100	72	80	41
White-headed vulture	120	41	34717	92	41	56	5
Hooded vulture	35	10	37888	33	5	14	2
Bearded vulture	10	4	35898	24	6	7	2

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33 Discussion

34 Our study shows that use of SFS in South Africa is widespread, and they provide enough
35 food to potentially fill almost all the energetic needs of the entire South African vulture
36 population. Provisioned food was not distributed evenly, with some species having low
37 access to SFS through their range. Therefore, vultures in the area are exposed to varying
38 amounts of provisioned meat quantities and types, and the associated risks of provisioned
39 food of which many SFS managers remain unaware. The numbers of active SFS have
40 remained stable over the past decade.

41

42

43 **SFS trends**

44 The initial increase in SFS from the 1970s onwards can likely be ascribed to various
45 awareness campaigns promoting the establishment of SFS to local landowners and the
46 general public (Mundy et al. 1992). Combined with increased awareness of vulture declines,
47 this may have accounted for the growing adoption of SFS by landowners. If the growth rate
48 of SFS remained consistent since that of 2002, then today there would be 430 active SFS in
49 South Africa (Anderson, Piper, & Swan, 2005). Our results show a similar increase up to the
50 year 2002, but a reduction in this rate afterwards, with SFS numbers plateauing in 2009.

51

52 **Adherence to best practices**

53 Livestock dominates the food provisioned by SFS in most areas. Due to widespread use of
54 veterinary drugs in livestock production, many scavenger species may be exposed to these
55 substances (Blanco et al., 2016; Blanco, Junza, & Barrón, 2017) in a similar way as reported
56 for Asian vultures (Shultz et al., 2004). Other veterinary drugs such as antibiotics may have
57 unidentified long term sub-lethal effects that can influence the fitness of scavengers
58 (Pitarch, Gil, & Blanco, 2017). Game meat was provisioned at 34% of SFS and mostly
59 originates from hunting activities. This provisioned meat may therefore contain lead
60 fragments from spent lead ammunition. This is problematic as the harmful effects of lead on
61 avian taxa are well documented (Haig et al., 2014). Lead is known to accumulate in vultures
62 in southern Africa and a worrying amount of individuals display lead levels consistent with
63 subclinical to severe clinical effects (Garbett et al., 2018; Krüger & Amar, 2018; van den
64 Heever et al., 2019). Ingestion of lead fragments in carcasses have been indicated as the
65 most likely cause of these elevated lead levels as these elevated levels were not found in
66 non-scavenging species and were also associated with hunting season and areas (Garbett et
67 al., 2018; van den Heever et al., 2019).

68 The safety of the food provided at SFS depends on how aware managers are of
69 threats, and how seriously they take them. In South Africa, our survey suggested that 28% of
70 SFS managers were unaware of potential harmful effects of veterinary drugs and 68% were
71 unaware of the harmful effects of lead. Consequently, carcasses provided at many SFS could
72 be contaminated with these harmful substances, which could have a negative impact on the
73 vultures that consume them. Another indication that best practice is not always followed is

74 illustrated by the small percentage of SFS that are providing poultry carcasses, potentially
75 exposing vultures to avian influenza (Ducatez et al., 2007). Some respondents also reported
76 powerline associated mortalities at their sites which represents a main contributing factor
77 for the closure of 7% of SFS. This indicates that some SFS may potentially increase the
78 collision and electrocution risks to vultures. We suggest that conservation practitioners
79 should work more in connection with SFS managers in order to increase their awareness of
80 these unintended consequences and reduce their likelihood through promoting best
81 management practices. In cases where negligent management practices are resulting in
82 mortalities of endangered species, the relevant authorities should intervene.

83

84 **Temporal variation in SFS provisioning: a paradox**

85 Our updated information on distribution and food provision of SFS in South Africa will allow
86 in-depth analyses of how SFS may influence space use of vultures. Vultures have historically
87 evolved to use temporally variable and unpredictable food resources (Monsarrat et al.,
88 2013). Conversely, regular feeding at SFS associated with intensive livestock farming
89 operations, could lead to the development of routine behaviours and dependence (Fluhr et
90 al., 2017). Within an African context, limited information exists on this potential impact of
91 SFS on vulture behavior. Anecdotal knowledge in Southern Africa suggests this may be
92 species-specific. For example, dependence on SFS seems low for the Cape vulture (Kane et
93 al., 2016), but high for non-adult bearded vultures (Reid et al., 2015).

94 Paradoxically, while foraging naturally, vultures may have an increased risk to come
95 into contact with carcasses that have been laced with poison (Monadjem et al., 2018).
96 Regular and copious provisioning of safe food at SFS could thus lead to a reduction in
97 poisoning risk. Initially, SFS were only viewed as a temporary means to 'buy time' for
98 addressing the ultimate threats that are causing vulture declines. Unfortunately, after 40
99 years since the introduction of SFS, the threat of poisoning is still high, and SFS have become
100 an established tool for general application.

101

102 **Expansion of the SFS network**

103 Many conservation organisations promote the establishment of SFS (Birds of Prey
104 Programme, 2007). They do so based on different unverified assumptions e.g. that SFS
105 reduces localized poisoning risk, that SFS can divert vultures from areas of high risk and that
106 in the absence of SFS, vulture populations experience food shortages. In order for the
107 expansion of the existing SFS network to be evidence-based, such assumptions first need
108 verification through scientific investigation. Once evidence for a measurable net positive
109 impact on vulture demographic parameters has been obtained, then this tool can be
110 considered on a case-by-case basis. Given the current lack of such evidence, decisions on
111 SFS establishment are made in the dark (Cook, Hockings, & Carter, 2010).

112

113 **Future research**

114 Parts of the SFS database were already being used in research prior to this study and thus
115 prior to our verification (e.g., Krüger, Simmons, & Amar, 2015; Kane et al., 2016). A visual
116 comparison of the results of this study and the locations used by Kane et al. (2016) suggests
117 that roughly 22% of the 110 SFS included in their study were miscategorised. Their study
118 also omitted at least 70 active SFS. One of the aims of the present study is therefore to
119 provide up to date information that can assist future analyses exploring the influence of SFS
120 on vulture behaviour or demographics.

121 Future studies need to verify the basic assumptions on the demographic effects of SFS
122 on vulture populations. In addition, research should focus on quantifying the role of SFS in
123 reducing poisoning risk to vultures, e.g. by studying impacts on ranging behaviours. For
124 example, it may be that SFS could be strategically located to divert vulture movements away
125 from areas with a high threat of poisoning or wind turbine collision (Reid et al., 2015).
126 Finally, the effects of different feeding methods (regular vs. irregular feeding, whole
127 carcasses versus small food parcels) on the above factors and the structure and functioning
128 of the South African scavenger guild could be assessed. In Europe, increased predictability of
129 resources at SFS favoured more dominant species to the detriment of less competitive and
130 often more threatened vulture species (Cortés-Avizanda et al., 2012). Feeding methods
131 could thus play an important role when SFS are aimed at supporting a particular species in a
132 particular area.

133 Although we hope this study can assist in future research, SFS security is a concern.
134 There are fears that if SFS locations are made freely available, they could be exploited by
135 poachers for vulture harvesting, or that provided carcasses would be taken for human
136 consumption. Parties interested in using this data for research or management planning are
137 therefore encouraged to contact the authors directly so relevant data-agreements can be
138 arranged.

139

140 **Conclusion**

141 To assess the effectiveness of conservation interventions, it is crucial to know where, when
142 and how such interventions are implemented. A lack of this information prevents such
143 assessments, ultimately leading to a potential waste of scarce conservation resources that,
144 in the case of vulture SFS, may even have counterproductive effects. In this study, we
145 provide the necessary information to enable such research and provide conservation
146 managers with an updated view of the South African SFS network.

147

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156

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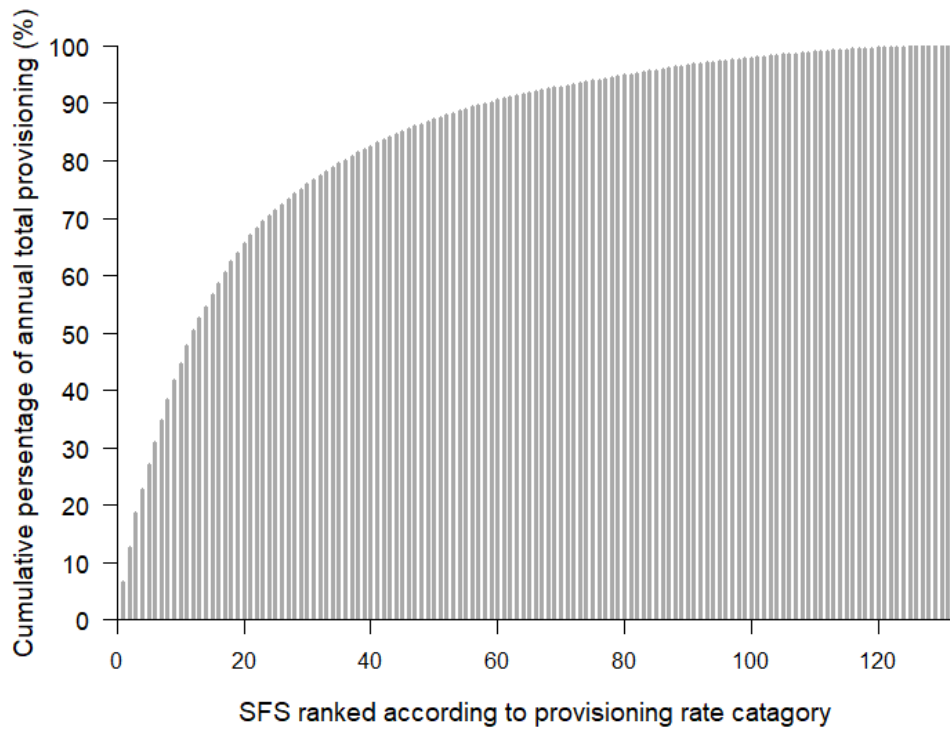
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388 **Appendix**

389 **Appendix 1:** South African population size and total annual food requirement estimates for six vulture species.

Common name	Scientific name	Number of adult vultures	Proportion adults	Population estimate	Daily food requirements (kg)	Annual food requirement (t)	Annual provisioning in species distribution (t/y)
African white-backed vulture	<i>Gyps africanus</i>	7350 ^a	0.67 ^b	10970	0.4 ^c	1601.6	2218.0
Cape vulture	<i>Gyps corprotheres</i>	8800 ^a	0.75 ^d	11733	0.52 ^c	2227.0	2448.9
White-headed vulture	<i>Trigonoceps occipitalis</i>	158 ^a	0.75 ^e	211	0.35 ^c	27.0	84.6
Lappet-faced vulture	<i>Torgos tracheliotos</i>	338 ^a	0.81 ^e	417	0.5 ^c	76.1	1190.0
Hooded vulture	<i>Necrosyrtes monachus</i>	150 ^a	0.65 ^f	231	0.35 ^c	29.5	120.1
Bearded vulture	<i>Gypaetus barbatus</i>	233 ^a	0.6 ^f	388	0.3 ^g	42.5	737.4
TOTAL		17029		23950		4003.6	

390 ^aTaylor et al. 2015, ^bMurn and Botha 2018, ^cMundy et al. 1992, ^dRobertson 1984, ^eKemp and Begg 2001, ^fBrown 1997, ^gDonazar 1993.



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392 **Appendix 2:** Supplementary feeding sites (SFS) ranked according to their annual provisioning rates,
 393 from highest to lowest, in relation to the cumulative contribution of each additional site, to the
 394 national total annual provisioning rate (expressed as a percentage).

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406 **Appendix 3:** Summary of the composition and distribution of the 3113 tonnes of annually provided food, at 143 verified active SFS, across all South African
 407 provinces. (LP = Limpopo, KZN = KwaZulu Natal, NW = North West, EC = Eastern Cape, GT = Gauteng, MP = Mpumalanga, FS = Freestate, NC = Northern
 408 Cape, WC = Western Cape).

409

Province	Verified active sites	TOTAL t/y	% of TOTAL	% Beef	% Game	% Pork	% Sheep	% Equine	% Other
LP	32	1198.7	38.5	35.9	27.6	30.4	4.1	0.2	1.7
KZN	51	752.4	24.2	56.4	10.9	25.3	1.6	3.7	2.1
NW	16	616.5	19.8	15.0	14.6	59.9	3.8	1.4	5.3
EC	21	246.8	7.9	89.1	0	2.2	5.9	2.7	0.0
GT	6	165.1	5.3	11.4	12.7	64.5	0.3	11.1	0.0
MP	6	78.4	2.5	13.6	82.2	0.0	0.4	3.8	0.0
FS	6	26.2	0.8	54.2	16.8	3.2	12.2	3.8	9.8
NC	4	16.2	0.5	20.2	61.9	0.0	3.9	14.1	0.0
WC	1	12.6	0.4	47.2	0.0	0.0	52.8	0.0	0.0

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411 **Appendix 4:** Vulture species home range sizes used for the calculation of SFS range coverage. The maximum buffer radius corresponds to the 95% Kernel
412 Density Estimates (KDE) for the given species. Only a 90% KDE was available for bearded vultures. For the minimum buffer size, 50% KDE was used.

Species	Scientific name	Average home range (km ²)	Maximum buffer radius (km)	Minimum buffer radius (km)	References
Lappet-faced vulture	<i>Torgos tracheliotos</i>	194 813	249	94	Garbett, 2018
African white-backed vulture	<i>Gyps africanus</i>	-	249 ⁱ	94 ⁱ	Spiegel, Getz, & Nathan, 2013
Cape vulture	<i>Gyps corprotheres</i>	110 181	187	56	Kane et al., 2016
White-headed vulture	<i>Trigonoceps occipitalis</i>	-	120 ⁱⁱ	41 ⁱⁱ	-
Hooded vulture	<i>Necrosyrtes monachus</i>	3913	35	10	Reading et al., 2019
Bearded vulture	<i>Gypaetus barbatus</i>	286	10	4	Krüger, Reid, & Amar, 2014

413 ⁱ Data unavailable, lappet-faced vulture values used here based on literature suggesting similar movement behaviour.

414 ⁱⁱ Data unavailable, average values of all other species for which data was available used.

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419 **Appendix References**

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Supplementary material:

Questionnaire

Date:

VR_Code (for office use):

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VULTURE RESTAURANT SURVEY:

Hello, my name is Christiaan W. Brink and I am a PhD student at the University of Cape Town researching the contribution of vulture restaurants to vulture conservation in South Africa. I found your contact details on our existing database in relation to a vulture restaurant / feeding site, and would appreciate it if you took part in our survey that will aid vulture conservation and which will ultimately benefit vultures and landowners. Your participation would be appreciated whether you are currently feeding vultures or have stopped doing so.

As part of my thesis I am updating the current database with the information of vulture restaurant managers. This information will not be published or made freely available to the public and will only be distributed to the relevant people in vulture conservation and research (eg. VulPro, EWT, Ezemvelo KwaZulu-Natal wildlife, all of which have contributed to, or is a collaborator on this project). Do you give consent for your information to be shared with the before mentioned people?

Participant agreed (Please remove if you disagree)

At the same time we would like to get an understanding of what motivates people to run vulture restaurants. Please answer the questions below. Please note that the answers from these questions (excluding the Basic Info) will not be included in the database but rather kept confidential. When the research is published, none of your answers will be linked with your name or name of your farm and so will remain anonymous.

Please note that your participation in this interview is completely voluntary.

Do you agree to participate in this interview?

Participant agreed (Please remove if you disagree)

A. Basic info/demographics

1. Name:
2. Position/role at the property: (i.e.: owner, manager):
3. Occupation:

4. Property owner name:
5. Name of property/farm:
6. Vulture restaurant property address:
7. Email:
8. Preferred contact number:
9. Coordinates of Vulture Restaurant (if not available, coordinates of property-please specify the structure for which coordinates are given):

C. Vulture Restaurant (VR):

10. Is the vulture restaurant still active, are you still feeding vultures?

[if closed] : _____

11. When did you stop putting out food for vultures?

12. What were the reasons why you stopped?

13. When did you start feeding vultures? (year and month if possible)

14. What was the motivation behind establishing and maintaining the vulture restaurant?

15. Please provide as accurate an estimate and description of what is provided at the vulture feeding site as possible: (eg. 2 Adult pigs per year (200-300kg per carcass); 10kg of Beef offal per day; 5 new born calves per month; Offal from 50 game carcasses during hunting season). We are fully aware that this may depend on stock losses and be variable but please make an attempt at providing some sort of rough estimate. Number of carcasses provided over the last year might be easiest. If closed please provide an indication of how much you used to feed.

16. Where is/was this food sourced from? (eg. My own property; neighbouring farmers donate; SPCA)

17. In your opinion do carcasses containing lead from spent ammunition pose any potential health threats to vultures (eg. Feeding on animals shot during hunting)? Please highlight chosen answer

- a. Yes
- b. No
- c. I don't know

18. In your opinion can veterinary drugs present in carcasses have any negative effects on vulture health? Please highlight chosen answer

- a. Yes
- b. No
- c. I don't know

Additional notes: