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Activity patterns of African White-backed Vultures *Gyps africanus* in relation to different land-use practices and food availability

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Changing patterns in land use in relation to the breeding distribution and foraging behaviour of the African White-backed Vulture *Gyps africanus* were investigated around Kimberley, South Africa. Recent land-use trends indicate a significant increase in game farming and a decrease in traditional cattle and sheep enterprises. Combined cattle and game farms were significantly larger than other farm types and associated with land-use activities that positively affect vulture behaviour. Vulture breeding colonies were found in *Acacia* woodland areas that are associated mostly with cattle farms and combined cattle and game farms. Food availability, as either livestock mortalities or animals wounded by hunters, was positively associated with vulture activity except on farms with sheep, which had less vulture activity than other farm types. The observed increase in area used for game farming is concluded to offer potential benefits to the resident African White-backed Vulture population.

Introduction

Raptors are sensitive to habitat modification brought about by land-use change and human activities (Herremans and Herremans-Tonnoeyr 2000, Avilés *et al*. 2001). Whilst some vulture species can adapt to human-modified environments, such as livestock farming areas (Robertson and Boshoff 1986, Scott *et al*. 2000), vultures clearly benefit from the existence of protected areas and occur at significantly lower densities outside them (Liversidge 1984, Aumann 1997, Herremans 1998, Rondeau and Thiollay 2004, Thiollay 2007).

Human development is associated with the construction of artificial structures, such as electrical powerlines and water reservoirs, and these are frequently significant causes of mortality for vultures (Anderson and Maritz 1997, Anderson *et al.* 1999). Secondary poisoning is also a constant threat to vultures due to their scavenging lifestyle (e.g. Anderson 1993).

The African White-backed Vulture *Gyps africanus* (AWbV) is a tree-nesting vulture that breeds in loose colonies (Mundy *et al.* 1992, Murn *et al.* 2002). The global population has been estimated at 270 000 birds (Mundy *et al.* 1992), with the South African population numbering about 9 000 individuals (Anderson 2000). It is most often associated with wooded savannas and the species has a marked preference for *Acacia* trees, particularly *Acacia erioloba* (Mundy *et al.* 1992, Anderson and Maritz 1997). Although AWbV breeding areas are often associated with *Acacia* woodland, it is unknown how the breeding distribution of the species relates to land-use practices. Similarly, AWbV foraging and feeding behaviour in a multiple land-use environment is unknown.

The greater Kimberley area in the Northern Cape and Free State provinces of South Africa is an important breeding area for AWbVs, and the population has been studied since the 1960s (Forrester 1967, Mundy 1982, Anderson and Maritz 1997, Murn *et al*. 2002). Apart from two localities in the southern Kalahari (Askham and Vanzylsrus), the greater Kimberley area is the only other important breeding area for AWbVs in the Northern Cape. The majority of AWbV nests in this province are located on private land outside protected areas (Anderson and Maritz 1997).

Across greater Kimberley, spatial and temporal variation in land-use patterns could affect vultures, particularly if they favour one land-use type over another. Identifying trends in land-use change is therefore an important part of the conservation management of AWbVs, especially as they may respond negatively to certain land-use changes. Food availability for vultures may be associated with some of the threats outlined above. The distribution and severity of these threats for the Kimberley AWbV population is unknown.

Using farm surveys and questionnaires, our objective was to determine how the distribution of AWbV breeding colonies and vulture foraging behaviour were related to land use and food availability in the greater Kimberley area.

Study area and methods

Study area

The study area is approximately 4 000 km^2 in size and located in the Northern Cape and Free State provinces of South Africa, surrounding the city of Kimberley. Domestic livestock and game farming are the typical agricultural types, resulting in a relatively low degree of landscape modification. Crop production and alluvial diamond mining have, however, resulted in significant habitat change adjacent to the main rivers in the study area, the Vaal and the Riet/Modder. Away from these rivers, habitat modification is either limited and localised, or absent.

The terrain around Kimberley consists of slightly irregular plains with a well-developed tree layer, scattered low hills (dolerite koppies) and occasional ephemeral pans. The vegetation type is Kimberley Thornveld of the Savanna Biome (Mucina and Rutherford 2006). Dominant tree species are camel thorn *Acacia erioloba* and umbrella thorn *A. tortillis*. There is an occasional well-developed shrub layer of black thorn *A. mellifera*, which in some areas has become excessively thick (bush encroachment). In other parts of the study area the soils are more lime prone, which results in virtually treeless areas dominated by shrubs such as vaalbos *Tarchonanthus camphoratus* and karee bush *Rhus lancea* (Gubb 1980). The annual rainfall average is between 380 mm and 420 mm, and falls mainly during the summer months.

Farm surveys

Farm surveys were conducted between May and July 2001, which corresponds to the immediate prebreeding and early breeding season for the local AWbVs. Eighty-two farms were visited across the study area and during each visit landowners provided responses to questions as part of a detailed interview and survey about vultures. Basic farm information comprised: (1) size of the property (ha); (2) farm type; (3) length of time that the present farming activity has been practised; and (4) previous land-use activities. The categories of farm type were: cattle only, game only, with sheep, combined cattle and game, and with crops.

Farmers advised how frequently they observed vultures (vulture frequency) on their properties (never; infrequently = once a month; often = once a week; most days = several times a week; every day) and what type of vulture activity occurred (feeding = yes/no, roosting = yes/no, breeding = yes/no). We considered it likely that a farmer's opinion of vultures would affect how often they reported seeing them. To assess the impact of this, farmers were asked two additional questions relating to their opinion of vultures (very negative; negative; neutral; positive; very positive) and how the local vulture population had changed in the last ten years (hardly any now; less now; no change; more now; far more now). Reported vulture frequency was also likely to be affected by the distance of a farm to the nearest vulture breeding colony. We measured the straight line distance from each farm to the nearest colony, using recent survey information (Murn *et al*. 2002).

Stock density and food availability

For each property, the total number of domestic stock and game animals was recorded and converted to a Mature Livestock Unit (MLU) equivalent. The MLU is primarily a mass-based rating and, based on the standard convention, one MLU is equivalent to one head of cattle with a mass of 450 kg (Scarnecchia 1985, Young 1992). Table 1 lists the stock and game species and their MLU equivalents used in this study.

Unless the number of steenbok *Raphicerus campestris* and common duiker *Sylvicapra grimmia* were known, their numbers were estimated from an extrapolation of pairs ha^{-1}. The expected home range sizes for steenbok and duiker individuals were 45 ha and 25 ha, respectively (Skinner and Smithers 1990).

Farmers were able to provide accurate figures on the number of stock deaths during the six months preceding the survey, which primarily covered the non-breeding season for AWbVs. We used this information to determine a potential food availability variable called 'six-month MLU'. This variable was combined with farmer information on seasonal stock mortality (e.g. calving deaths, plant poisoning etc.) to estimate yearly stock mortality rates.

Carcass disposal policy on farms affects the potential availability of six-month MLU to vultures. There were four recorded types of carcass disposal policy: 0 = carcasses always removed; 1 = carcasses removed if fresh; 2 = carcasses burnt, buried or otherwise removed if diseased; and 3 = carcasses always left out.

During the analysis, recorded stock deaths considered as completely unavailable to vultures were from farms only in category '0'.

Where farmers conducted hunting or culling operations, the number of animals shot provided a second potential food availability variable called 'hunt MLU'. This variable is an annual estimate of wounded animals that escape and are potentially available to vultures should they die. Wounded animals that escape and are not found are an inevitable part of hunting and culling. During the study, twenty experienced hunters and cullers provided estimates of 1–16% for wounded animals that escape. From these figures, an estimated 8% of all animals hunted or culled would have been wounded and potentially available to scavengers.

For both six-month MLU and hunt MLU, carcass visibility for vultures was treated as equal. Although bush encroachment or thickening occurs in some parts of the study area, it was impractical during this study to determine the extent of this and how it would affect carcass visibility.

Statistical analysis

Using logistic regressions and one-way analysis of variance, we tested how the four Vulture Activity Factors (Frequency, Feeding, Roosting and Breeding) varied against the following continuous land-use variables: farm size (ha); total number of animals; total MLUs; carrying capacity (MLU ha^{-1}); six-month MLU and hunt MLU.

We used contingency tables with Chi-squared analyses to test for relationships between the Vulture Activity Factors and categorical land-use variables: farm type; years as current farm type (four categories); hunting on farm (yes/no); culling operation on farm (yes/no); presence of a vulture restaurant (yes/no).

All continuous variables were assumed to be normally distributed, with constant residual variance. To normalise variance and distribution, continuous variables were $\log_e$ transformed. Normality was checked using Anderson-Darling tests. All tests and calculations were performed with Minitab.

Results

Farm types and land use around Kimberley

The 82 surveyed farms covered an area of 386 112 ha. Combined cattle and game farms were the dominant farm type and covered the largest proportion of the study area.

Table 1: Mature livestock unit (MLU) equivalents for game species and domestic stock, with recorded MLU totals across 82 farms around Kimberley, South Africa. Rating follows Scarnecchia (1985) and Young (1992).Total recorded MLU rounded to nearest whole number

Common name	Scientific name	MLU equivalent	Total recorded
Kudu	*Tragelaphus strepsiceros*	0.46	1176
Eland	*Taurotragus oryx*	1.11	1637
Gemsbok	*Oryx gazelle*	0.46	2170
Impala	*Aepyceros melampus*	0.16	334
Giraffe	*Giraffa camelopardis*	1.54	223
Blue wildebeest	*Connochaetes taurinus*	0.45	620
Black wildebeest	*Connochaetes gnu*	0.32	398
Zebra	*Equus* spp.	0.68	725
Red hartebeest	*Alcelaphus bucelaphus*	0.33	922
Mountain reedbuck	*Redunca fulvorufula*	0.10	57
Springbok	*Antidorcas marsupialis*	0.10	2361
Steenbok	*Raphicerus campestris*	0.03	14
Common duiker	*Sylvicapra grimmia*	0.06	22
Blesbok	*Damaliscus dorcas*	0.20	733
Ostrich	*Struthio camelus*	0.32	503
Waterbuck	*Kobus ellipsiprymnus*	0.43	104
Buffalo	*Syncerus caffer*	1.11	189
Rhebok	*Pelea capreolus*	0.09	1
Sable	*Hippotragus niger*	0.46	68
Roan	*Hippotragus equinus*	0.51	47
Nyala	*Tragelaphus angasii*	0.24	1
Lechwe	*Kobus leche*	0.22	5
Fallow deer	*Cervus dama*	0.30	22
Domestic stock			
Domestic goat	*Capra* spp.	0.20	83
Cow	*Bos* spp.	1.00	13115
Calf (<6 months)		0.13	126
Weaner (6–9 months)		0.25	853
Yearling		0.50	704
Bull		1.20	133
Sheep	*Ovis* spp.	0.20	1328
Lambs		0.04	18

Combined cattle and game farms were also significantly ($F_{4,77}$ = 4.93, P = 0.001) larger than other farm types and had a mean size of 7 180 ha (median 4 816 ha).

During the time frame of the survey (10 years), the number and area covered by game farms within the study area increased by approximately 250% and more than 600%, respectively (Figure 1). Of the 40 farms that experienced a change in land use over the 10 years prior to the survey, 73% incorporated game into the farming system. Of this proportion, 38% changed to game exclusively. Many 'new' game farms have changed from traditional cattle and sheep enterprises, which declined in number and area by approximately 40% over the same period.

Hunting occurred on over 80% of surveyed farms and approximately 13% of farms employed organised culling to remove excess game. Neither activity was significantly associated with any farm type.

Animal numbers, carrying capacity and available food

Across the 82 farms 75 578 animals of all kinds were recorded. This corresponded to a total MLU equivalent of 29 010. A further 8 500 steenbok and 15 400 common duiker were estimated to be present in the study area (1 184 MLU equivalent).

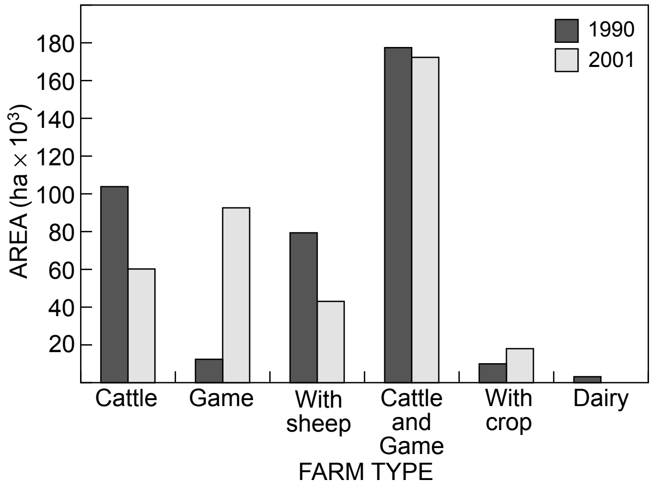

Figure 1: Changes in farm type areas between 1990 and 2001 around Kimberley, South Africa

Cattle dominated in terms of livestock, and were present on 73% of farms either exclusively or in combination with other farm types. Game farming was the second most common farming type, either exclusively or in combination with other farm types on 67% of properties.

Carrying capacity (MLU ha^{-1}) did not change significantly across different farm types. Due to their larger average size, combined cattle and game farms had significantly more ($F_{4,77}$ = 3.79, P = 0.007) animals and higher MLU equivalent totals ($F_{4,77}$ = 5.22, P = 0.001) than other farm types.

Six-month MLU and hunt MLU were not significantly related to land-use type. However, residual variance was outside test assumptions for these variables. Figure 2 (untransformed data) suggests that six-month MLU and hunt MLU does vary between farm types, with combined cattle and game farms appearing to have higher potential food availability.

Stock mortalities were more numerous during the spring and summer months. Farmers reported that plant poisoning, disease and calving problems were prevalent at this time. Relative to the autumn and winter months, food supply is potentially higher at these times.

Vulture activity and land use

There were no significant results when comparing farm type against vulture frequency. Not unexpectedly, reported vulture frequency decreased with distance from a vulture breeding colony (Z = 4.15, P < 0.001, Pearson goodness-of-fit: P = 0.847). However, there was no significant relationship between distance from a colony and farm type, or farm types surrounding each breeding colony.

One property adjacent to a breeding colony, and a surprising number of others (11), reported never seeing vultures. It was thus possible that farmer opinion would affect reported vulture frequency. However, the vast majority of farmers (90%, n = 74) had a positive opinion of vultures and we did not observe any relationship between vulture frequency and farmer opinion (Figure 3). The very high proportion of farmers with a positive opinion of vultures prevented a meaningful examination of how farmer opinion might have affected reporting rates. There were no farmers with a very negative opinion of vultures and it is notable that the three farmers with a very positive opinion of vultures only reported seeing them infrequently.

Despite this limitation, vulture frequency did vary according to land-use change over time. Properties that had recent land-use changes reported the frequencies 'never' and 'infrequently' significantly more (χ^2 = 23.3, $P < 0.05$) than properties that had not changed land use over the last 20 years (Table 2).

The relationship between breeding and land-use change over time was also significant (χ^2 = 8.65, $P < 0.05$), and followed the same pattern as vulture frequency.

Vulture feeding activity was strongly associated (χ^2 = 16.3, $P < 0.01$) with game farms, and combined cattle and game farms. Vultures were breeding more frequently than expected (χ^2 = 10.6, $P < 0.05$) on cattle farms, and combined cattle and game farms. In contrast, vultures fed and bred less than expected on farms with sheep.

Larger farms with more animals had significantly more feeding activity ($F_{1,80}$ = 2.52, P = 0.014) and roosting activity ($F_{1,80}$ = 10.73, P = 0.002), and vultures were reported more frequently on larger farms (Z = –2.16, P = 0.031, Pearson goodness-of-fit: P = 0.519). The total number of animals or farm size did not appear to influence where vultures breed, and there was no observable relationship between carrying capacity (MLU ha^{-1}) and any of the vulture activity factors.

The presence of a vulture restaurant (feeding station) on a farm had a significant positive influence on all vulture activities. There is, however, a paradox associated with testing the effect of vulture restaurants on vulture activity. It is not possible to determine if the increased frequency of vulture activity is a result of the restaurant itself, or the fact that farmers who provide a restaurant are more interested in watching for vultures.

Apart from this paradox, there were insufficient data to draw any conclusions about the occurrence of vulture restaurants on any particular farm type. The most obvious feature of the 12 restaurants and their occurrence is that more than half (n = 7) are located on combined cattle and game farms. The total amount of food reported to be deposited at all these restaurants during the six months before the survey was 8.22 MLU, or 2 400 kg, of available meat.

Culling activity on a farm had a positive influence on vulture feeding activity (χ^2 = 5.898, $P < 0.05$), but the relationship between hunting and vulture feeding activity was weak (χ^2 = 3.072, P = 0.08). Hunting did not appear to influence any other vulture activities.

Vulture activity and available food

Reported stock deaths for the previous six months (six-month MLU) was 180 MLU equivalents, or approximately 1% of the total number of animals. This corresponds to a total animal mass of approximately 81 000 kg. Assuming a similar stock death rate across a 12-month period, nearly 162 t of dead animals were potentially available to vultures and other scavengers.

Six-month MLU was strongly associated with vulture frequency (Z = –3.98, P = 0.000, Pearson goodness-of-fit: P = 0.679). Taking into account farm carcass disposal policy, vulture feeding activity ($F_{1,80}$ = 7.23, P = 0.009), roosting ($F_{1,80}$ = 10.05, P = 0.002) and breeding

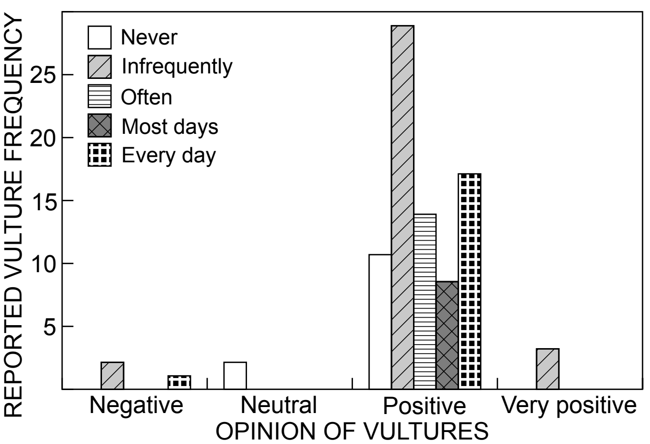

Figure 3: Reported vulture frequency in relation to farmer opinion around Kimberley, South Africa

Table 2: Change in reported vulture frequency in relation to land-use change around Kimberley, South Africa

Time as farm type	Relative reported vulture frequencies[a]				
	Never	Infrequently	Often	Most days	Every day
0–5 years	++	+	+	-	--
5–10 years	++	+	0	-	--
10–20 years	+	0	0	0	0
>20 years	--	-	0	+	++

[a] ++ = strong positive relationship, + = positive relationship, 0 = no observable relationship, - = negative relationship, -- = strong negative relationship

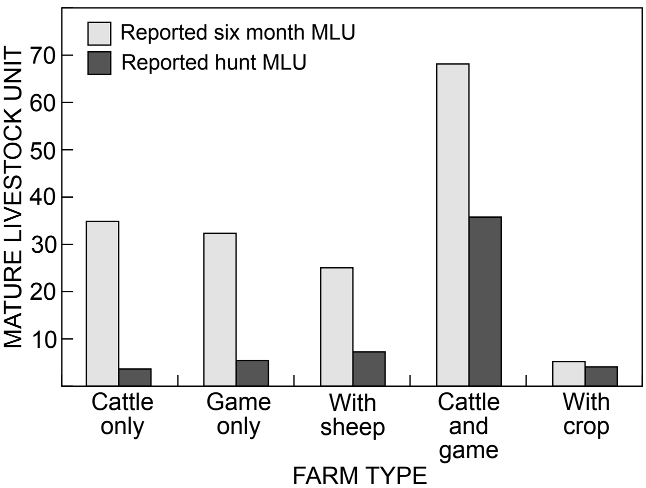

Figure 2: Total reported stock and hunting mortalities by farm type around Kimberley, South Africa

($F_{1,80}$ = 10.83, P = 0.001) were positively associated with six-month MLU. Carcass disposal policy was an important determinant of food availability.

Reported hunt MLU was provided as an estimate during one year, which totalled 56 MLU or 25.2 t. Added to this is the estimate of unrecorded hunting casualties, which was calculated at 71 MLU or 32 t.

Vultures were reported more frequently on farms with high levels of hunt MLU (Z = –2.53, P = 0.011, Pearson goodness-of-fit: P = 0.759). Vulture roosting ($F_{1,80}$ = 10.79, P = 0.002) and breeding ($F_{1,80}$ = 6.58, P = 0.012) were significantly related to high levels of hunt MLU, but not feeding (P = 0.093). However, variance of residuals was higher than test assumptions for hunt MLU, which lowers confidence in these results. An examination of the untransformed data illustrates some clear trends (Figures 4 and 5).

Overall, we found that a combination of farm type and food availability determines vulture activity. Food availability is the primary determinant for all vulture activity factors, including frequency, but there was insufficient power to identify greater food availability on one or more farm types. Despite the lack of statistical power, it would appear that combined cattle and game farms potentially provide more food.

Apart from food availability, the variables and factors most influential on vulture activity are most commonly associated with combined cattle and game farms. These relationships are summarised in Table 3 and Table 4.

Discussion

Land use, available food and vulture activity

Across the greater Kimberley area, there has been a trend towards increased game farming, and our results indicate that this has consequences for the resident AWbV population. Specifically, the introduction of game into a farming operation (particularly a cattle operation) appears to offer more food, and this affects vulture behaviour. Both game farms and combined cattle and game farms were strongly associated with vulture feeding activity.

Elsewhere in southern Africa, the trend of increased game farming has been suggested to result in a range increase for AWbVs (e.g. Piper and Johnson 1997), which may refer to a foraging range and/or breeding range. Whilst AWbV feeding around Kimberley may be associated with game farms (in addition to other farm types), the breeding areas do not follow the same pattern.

Similarly, the creation of new protected areas may benefit AWbVs (Benson 1997) and it is clear that protected areas are important for the existence of significant AWbV breeding colonies (Monadjem and Garcelon 2003). Despite the benefits of protected areas, they do not appear entirely relevant for AWbVs around Kimberley, where game farming incorporated into a commercial cattle operation appears to be the land-use type most favourable to vultures.

The continuation or increase of commercial cattle farming is sometimes considered a negative land-use trend, particularly where vultures preferentially frequent areas with abundant game, such as in Botswana (Borello 1987). However, it is clear from this study and others (Robertson and Boshoff 1986, Scott *et al*. 2000) that vultures can

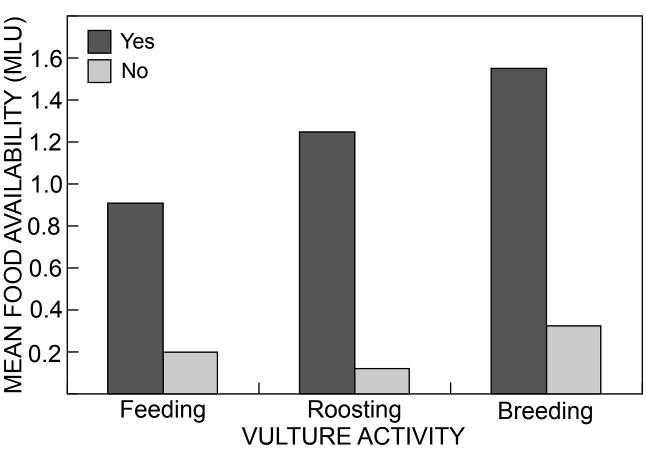

Figure 4: Comparison of vulture activity on properties around Kimberley, South Africa, in relation to reported food availability

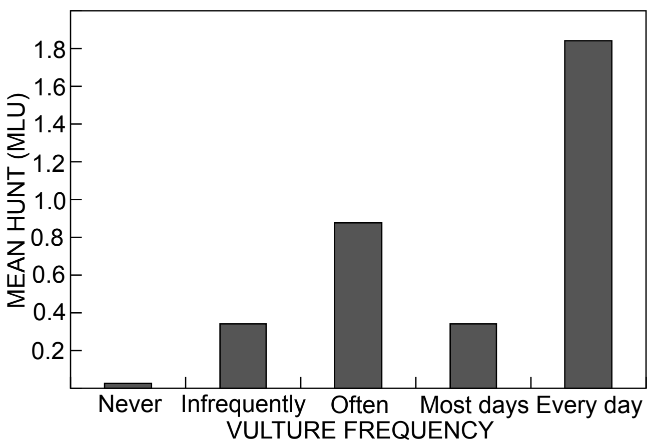

Figure 5: Reported hunting casualties in relation to vulture frequency around Kimberley, South Africa

Table 3: Summary relationships between vulture activity and land-use variables around Kimberley, South Africa (see text for description of land-use variables). MLU = mature livestock unit

Land-use variables	Vulture activity[a]			
	Frequency	Feed	Roost	Breed
Farm type	0	++	0	+
Years as farm type	+	0	0	+
6-month MLU	++	++	++	++
Hunt MLU	+	(+)	++	+
Farm size	+	+	++	0
Number of animals	+	++	++	(+)
Number of MLUs	(+)	+	++	+
MLUs ha^{-1}	0	0	0	0
Vulture restaurant present	++	++	+	++
Culling present	0	+	0	0
Hunting present	0	(+)	0	0

[a] ++ = strong positive relationship, + = positive relationship, 0 = no observable relationship. Parentheses indicate relationships approaching significance (P < 0.1)

Table 4: Observed relationships between identified land-use variables of importance to vultures and farm types around Kimberley, South Africa. MLU = mature livestock unit

Land-use variable	Farm type[a]				
	Cattle only	Game only	With sheep	Cattle and game	With crop
Farm type vs vulture feeding	0	+	–	+	0
Farm type vs vulture breeding	+	0	–	+	0
Years as farm type	0	0	0	0	0
Vulture restaurant	0	0	0	0	0
Culling present	0	0	0	0	0
Hunting present	0	0	0	(+)	0
Farm size	0	–	–	+	0
Number of animals	0	0	0	+	0
Number of MLUs	+	0	0	+	0
Six-month MLU	0	0	0	(+)	0
Hunt MLU	0	0	0	(+)	0

[a] + = positive relationship, 0 = no observable relationship, – = negative relationship. Parentheses indicate relationships approaching significance ($P < 0.1$)

adapt and persist in areas with domestic livestock, particularly if breeding birds are given at least some protection (Monadjem 2004) or left undisturbed.

The question of what is most favourable to AWbVs therefore remains. Is it more game farming, extended protected areas or continued domestic livestock? Our conclusion, based on AWbV activity around Kimberley, is that a combination of all of these land-use types is important. Food availability and the land-use practices governing it (Tables 3 and 4) are more relevant than land-use *per se*.

It is not unexpected that food availability is a primary indicator of vulture activity. Vultures of the genus *Gyps* can range well over 100 km per day in search of food (Ruxton and Houston 2002, Gilbert *et al*. 2007) and can theoretically make use of food wherever it becomes available. Although AWbVs are not territorial, preferred areas of occurrence are likely to be near the breeding colonies, particularly during the breeding period (May–November). This is one explanation of why farmers nearer to the breeding colonies, regardless of their farm type, see vultures more frequently.

Apart from land-use type, large farm size should be a good indicator of feeding and roosting activity because larger farm sizes generally have more animals, and thus more potential food. Around Kimberley, combined cattle and game farms are again significant in this regard. It is reasonable also to associate increased roosting activity with areas of increased feeding activity. However, as opposed to potentially wide-ranging feeding and roosting behaviour, breeding distribution is spatially discreet and restricted to suitable woodland, independent of food availability.

Although most of the land-use factors and variables associated with breeding are related to food (Table 3), these features are also most associated with cattle farms and combined cattle and game farms. Whilst vultures bred more often than expected on these two farm types, this is concluded to be more a result of them generally occurring in areas of woodland (as opposed to sheep and/or crop farms), rather than solely due to increased food availability. Despite this, not all areas with *Acacia erioloba* woodland have breeding vultures. We concluded that areas of woodland without breeding vultures are likely to consist of smaller (possibly game only) farms, have a greater incident of human disturbance, and/or be areas of reduced food availability.

These conclusions are supported by the fact that the six breeding colonies within the study area are almost exclusively located on larger, more established farms. These farms are either long-term cattle operations with significant woodland areas, or are farms that were traditionally cattle operations and have introduced game as well.

Although combined cattle and game farms are associated with the land-use practices that influence vulture behaviour, this relationship was observed less for farms with game only (Table 4). There are two main reasons for this. Firstly, many game farms are relatively small. An examination of small farms in the study area (<1500 ha) shows that 48% are game farms. Secondly, 28% of game farms surveyed have no hunting at all, and many others have only limited hunting. Conversely, every combined cattle and game farm had hunting (and resultant hunt MLU).

We made a distinction between farms with game as part of the management system, and those where game is an incidental feature of the area. With regard to the former, our results suggest that patterns in vulture activity are positively related to an increase in the frequency of game farming. We conclude that this increase is likely to be a positive trend for the local vulture population, particularly if it occurs on larger farms and is incorporated into an existing cattle operation.

The lack of vulture activity on sheep farms might be attributed to a number of factors. A feature of most sheep farms in the study area is a lack of woodland. This would clearly inhibit the establishment of breeding colonies and, in the absence of suitable electricity pylons, might also reduce the incidence of roosting. A second feature is that many sheep farmers monitor their stock more closely than cattle or game farmers, to the point where many will muster their flock each night and keep them in holding kraals (paddocks). This management technique, which would affect food availability for vultures, would not have been realised but for the farmer interview technique.

Farmer surveys and data collection

Although time consuming and labour intensive, the interview technique was considered preferable to a postal survey for a number of reasons:

(1) Completion of the questionnaire was guaranteed once an interview had been secured, and no requests for an interview were rejected. Responses to postal questionnaires are often slow, incomplete and with a low poll (Boshoff 1980, Robertson and Boshoff 1986). It is also likely that only interested people will reply, possibly leading to erroneous and biased results.

(2) Farmer opinions and reactions could be assessed more easily. Similarly, the reasoning of answers to particular questions could be conveyed.

(3) Additional information that would not necessarily be included in a written reply could be recorded (e.g. sheep management, see above).

(4) It was considered a valuable public relations exercise in order to increase awareness of raptor conservation and research. Apart from data relating to land use and food availability, gauging local opinion towards vultures is an important step to evaluating conservation and management strategies.

Although we concluded that landowner opinion did not significantly affect reported vulture frequency, a remaining difficulty in the survey technique is that the reported frequency of vulture occurrence is necessarily subjective. Several farmers commented that there were no vultures at all around Kimberley, and that the authors had come to the wrong area. There are several explanations for this.

In relation to the human eye, AWbVs generally fly quite high at about 300 m (Mundy *et al.* 1992). It is difficult to see vultures at this altitude unless one is actively searching for them. Additionally, whilst outdoors, farmers are usually working and have little time to watch the skies for vultures.

An estimate of 12-month MLU would have been more useful for analysis, but it became apparent during the survey that only a small number of farmers could accurately report the number of stock deaths in the preceding 12 months. Due to variation in seasonal mortality, three months would not be sufficient to assess any possible trends. Six months appeared to be the limit of accurate reporting. Although there are possible deficiencies in this technique, it is a more accurate assessment of stock mortalities than extrapolation based on the average of a small number of farms. Additionally, the variation in stock types (cattle, sheep and game) and their mortality rates further reduced the validity of the extrapolation method.

An accurate food supply from game mortality could not be quantified because game is not monitored as intensively as livestock. Without a weekly head count, a game farmer on a medium-sized property (5 000 ha to 10 000 ha) can rarely record how many animals become available to vultures. On large properties (>10 000 ha) estimating game mortalities literally becomes impossible (P Phelan pers. comm.).

In terms of the hunt MLU estimate, few interviewees were eager to report how many animals they had wounded and not subsequently located during a hunting season. As a result, the survey was modified to record how many animals were shot and then the estimated 8% wounded rate was used to calculate numbers of wounded animals. Reported hunt MLU is likely to be an underestimate. Statistical tests involving hunt MLU were compromised by numerous outliers and a lack of constant residual variance. A re-examination of the completed survey forms revealed that outliers in the analysis were the respondents who were not concerned with advising numbers of wounded animals.

Overall, the farmer questionnaire survey was useful for obtaining valuable data on food availability and threats to vultures, but less useful for assessing vulture frequency. Vulture frequency would be better assessed using carcass placements, carcass watches and observational transects.

Land-use practices and vulture populations

Although carcass disposal policy has a significant impact on vulture feeding behaviour and the availability of food, there is an inherent difficulty with altering farm carcass policy in favour of vultures. Many farmers do not want to leave carcasses out because it is reputed to encourage black-backed jackals *Canis mesomelas* and disease. Cattle farmers were not particularly concerned about jackals as a threat to their operation, and the same was observed for game farmers. Surprisingly, combined cattle and game farmers were very concerned about jackals.

If the level of conflict between farmers and jackals increases in the future, a possible outcome is the resumption of widespread jackal control operations, in particular poisoning. This has potentially serious consequences for the vulture population. It is perhaps ironic that an increase in game farming might lead to more food for vultures, but might also lead to increased risk of secondary poisoning.

Similar to carcass disposal policy, vulture restaurants may have a significant positive effect on food availability although, in our study, we found the amount of food deposited at the restaurants was low. We were unable to confirm that increased vulture activity at the restaurants was due to the restaurants or the increased interest of the farmers providing them, but other studies have shown that restaurants can increase vulture feeding activity where they are located (Bamford *et al*. 2007, Gilbert *et al*. 2007). Vulture restaurants are thus potentially important for the conservation management of vultures.

Vulture restaurants also have important ecotourism value and possibly environmental education value. They provide a valuable opportunity to study vulture behaviour and obtain colour ring/wing tag resighting information. For these reasons, we conclude that the establishment and monitoring of vulture restaurants in the greater Kimberley area (and elsewhere) is important.

Other aspects are relevant to the conservation management of the AWbV population in the greater Kimberley area. The effects of temporal food availability and the impact of various mortality factors (such as powerline interactions and lead ingestion) have the potential to affect the vulture population and are being investigated (Murn and Anderson unpubl. data).

However, if the trend towards an increase in game farming continues, feeding opportunities (if not food availability) for vultures are likely to increase. Provided the existing cattle farms and combined cattle and game farms that offer secure breeding habitat for vultures remain, the prospects for vultures in the greater Kimberley area from a land-use perspective appear favourable.

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