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Research Article

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Social media as a tool to understand the distribution and ecology of elusive mammals

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Abstract

Comparatively little is known about the distribution and ecology of Aardvark (*Orycteropus afer*) and Temminck's Ground Pangolin (*Smutsia temminckii*). Both are elusive species that are normally nocturnal, solitary, and fossorial. Formally collected records have been used to map the distribution of these species, and social media records provide a tool to gather information on their distribution and ecology. We obtained 680 photographs and videos of aardvarks and 790 of ground pangolins in southern Africa from publicly available posts on Facebook and Instagram (2010–2019). The images provide new insights into the distribution, activity, drinking, and predation—and confirm that aardvarks are more diurnally active when they are in poor body condition. Social media can provide useful supplementary information for understanding of elusive mammals. These "soft" data can be applied to other species.

Key words: activity pattern, biodiversity, body condition, distribution, southern Africa.

The conservation of mammals in the face of threats such as illegal trade, habitat loss, and climate change requires the regular collection of data on the abundance and distribution of those animals, as well as the factors influencing their ecology. Direct monitoring of most mammals is costly and labor-intensive, so proxy methods such as camera trapping, transects for animal signs, and molecular techniques such as environmental DNA metabarcoding have instead been used. Even with those proxy methods, elusive species are particularly difficult to monitor, often resulting in major knowledge gaps. The Aardvark (*Orycteropus afer*) and Temminck's Ground Pangolin (*Smutsia temminckii*) are 2 such species—they are challenging to detect as they are primarily nocturnal, solitary, occur at low densities, and are fossorial (Ingram et al. 2019; Epps et al. 2021).

The ground pangolin is listed as vulnerable on the IUCN Red List of Threatened Species (IUCN 2019; Pietersen et al. 2019) and is threatened primarily by illegal trade and harvesting (Challender et al. 2015; Tenorio and Baril 2019), habitat destruction, road mortalities, and electrocution by electrified fences (Beck 2008; Pietersen et al. 2014b). More recently, climate change—through its effect on ant and termite availability—has been identified as an additional threat (Panaino et al. 2022). The indirect impact of climate change on termite availability has also been identified as a threat to the Aardvark (Rey et al. 2017; Weyer et al. 2020), despite the species currently being classified as of Least Concern (Taylor and Lehmann 2015; Taylor et al. 2016).

Aardvarks and ground pangolins perform key roles in their ecosystem as predators of social insects and as creators of burrows. As predators of ants and termites, they contribute to the control of insect populations (Chao et al. 2020). Through their digging of burrows, they impact soil processes, including turnover of soil organic matter, acting as bioturbators that expose underground insects to other predators (Taylor 2013; Irshad et al. 2015; Chao et al. 2020), and provide burrows that are used by other species that are incapable of digging burrows themselves (Whittington-Jones et al. 2011). Given the knowledge gaps for both species, increasing threats to their survival, and their ecological importance, it is important to improve monitoring.

One way to supplement the efforts of researchers is through citizen science (Chandler et al. 2017). A citizen science platform such as iNaturalist provides millions of digitally verified biological sightings (Di Cecco et al. 2021) but has few high-quality records for aardvarks and pangolins. Another less formal platform for species observations, which may provide additional data from a broader base of observers, is social media. A recent survey of geotagged posts of Twitter and Flickr for the word "pangolin"

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confirmed the presence of pangolins within the IUCN geographic ranges (Di Minin and Hausmann 2020), while Instagram posts with the identifiers #monkseal provided information on Hawaiian Monk Seal (*Neomonachus schauinslandi*; Sullivan et al. 2019). Social media has also been used to elucidate ecological processes, as shown through a recent study using Facebook records of trophic interactions for southern African herpetofauna as predators and as prey (Maritz and Maritz 2020).

We hypothesized that publicly available social media records would provide information on the distribution and ecology of aardvarks and ground pangolins. We searched posts on Facebook and Instagram for photographs and videos of aardvarks and ground pangolins in southern Africa, and summarized the distribution of records, as well as other information on the ecology of each species.

Materials and methods

Data collection

We searched publicly available posts from 2010 to 2019 on Facebook and Instagram for photographs or videos of aardvarks and ground pangolins. Search terms used (Supplementary Data SD1) included the scientific and common species names used in southern Africa. We collected posts with clear (species definitely identified) images or videos of aardvarks or pangolins, including those from camera traps. Posts were manually filtered to remove images where animals were captive or reintroduced into the wild or poached. Images where animals appeared to have died of natural predation were included. Searches were restricted to southern African countries including South Africa, Namibia, Botswana, Zambia, Zimbabwe, Malawi Mozambique, Angola, Lesotho, and Eswatini, but no records were found for Angola, Lesotho, or Eswatini. Links to the posts used in our study are available in Supplementary Data SD2 and SD3.

Data capture and processing

Data from posts on Aardvark and ground pangolin were captured in a spreadsheet. The source of the photograph included (Facebook or Instagram) the date of the posting, and the location where the photograph was taken (country, province/region, and place within the province/region). Duplicates were removed where the same animal appeared to have been photographed by more than 1 person at a similar time, posted more than once by the same person, or posted on both Facebook and Instagram. The date of the posting was used to code the images as occurring in spring (September to November), summer (December to February), autumn (March to May), or winter (June to August). Each photograph was inspected, and the time of day coded as: daytime (not specified), morning, afternoon, or nighttime (18:00 to 06:00). Where time of day was not indicated on the post, light intensity, the use of a spotlight, and whether camera trap images are gray scale (infrared, after dark) or color (daytime) of the animal were used to code day or night (transitional periods where we could not be sure of the cutoff were classified as night). Camera trap images typically provided exact time detail. Animals were classified as to whether they appeared to be alive or dead, and if dead, whether a predator was captured in the image. Whether an animal appeared to be drinking also was recorded.

Body condition assessment

The body condition of aardvarks was assessed using a visual appearance scale ranging from 1 = "emaciated" to 4 = "fat" (adapted from Russel 1984; Thompson and Meyer 1994; Weyer 2018; Supplementary Data SD1). Two reviewers (LCRM, NMW) experienced in working with aardvarks scored the images independently. Where there was disagreement between the 2 reviewers, a third reviewer (MVP) arbitrated. Of the Aardvark images, 481 of 680 were suitable for rating body condition. The body condition of ground pangolins cannot be assessed visually as the animals are covered by scales.

Data analyses

Analyses were conducted using R (v4.2.0; R Core Team 2022), with the *ggplot2* package (Wickham 2016) used to generate plots. The number of posts of aardvarks and ground pangolins was determined for each country. For South Africa (the country that accounted for most posts), the data were separated by province. For southern Africa, the annual and seasonal patterns of sightings (stratified by time of day), and the number of drinking and predation (stratified by predator) events were summarized. Based on feedback from the body condition reviewers, before analyzing the relationship between body condition and the time of day that the sighting took place (daytime or nighttime), body condition data were collapsed into 2 groups: poor condition (condition scores of 1 or 2), and good condition (condition scores of 3 or 4). These data were then analyzed using logistic regression with time of day (daytime vs. nighttime) as the outcome measure.

Results

After cleaning the data, we had 680 photos and videos of aardvarks and 794 of ground pangolins. South Africa had more than 80% of each (Table 1).

Further analysis of the posts from South Africa revealed that aardvarks were seen in all provinces, with most of the sightings in the Northern Cape (34%), followed by Limpopo (19%), and the Eastern Cape (18%; Fig. 1). Ground pangolin posts were in 4 provinces only, Northern Cape (50%), Mpumalanga (34%), Limpopo (14%), and North West (2%; Fig. 1). Aardvark (146) and pangolin (316) sightings were most common at Tswalu Kalahari Reserve in the Northern Cape, followed by Kruger National Park (98 aardvarks, 289 pangolins; Supplementary Data SD1). Data collected for South Africa revealed that aardvarks and ground pangolins were seen in all seasons.

Across the whole of southern Africa, most Aardvark posts were from observations in winter (47%), followed by spring

Table 1. Source of Aardvark and Temminck's Ground Pangolin images by country

Country	Aardvark	Ground Pangolin
	Count (%)	Count (%)
South Africa	571 (84)	673 (85)
Namibia	46 (5)	31 (4)
Botswana	23 (3)	34 (4)
Zambia	23 (3)	19 (2)
Zimbabwe	8 (1)	5 (1)
Malawi	5 (1)	19 (2)
Mozambique	4 (1)	13 (2)
Total	680	794

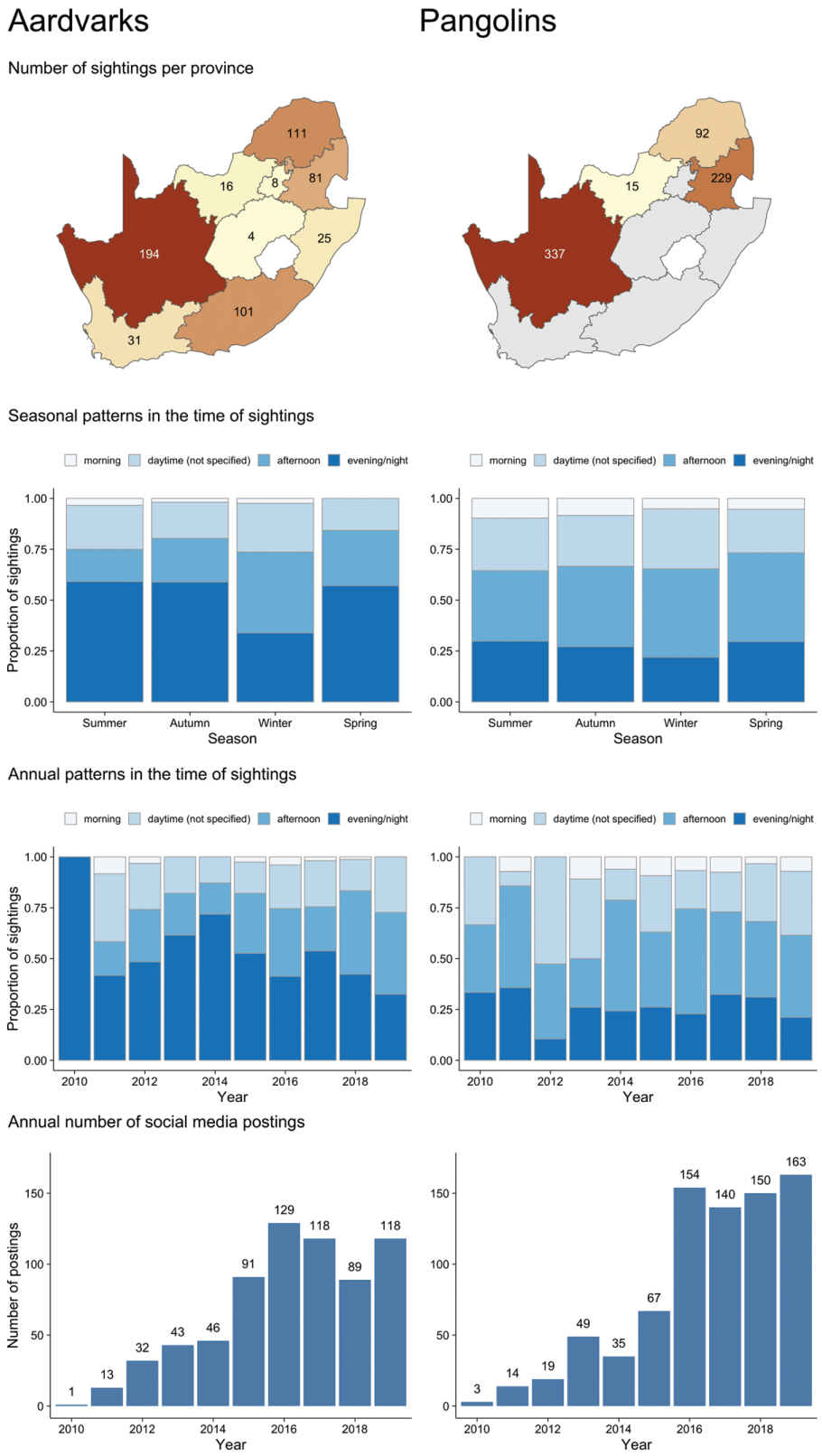

Fig. 1. The number of distinct posts of aardvarks (left) and ground pangolins (right) in South Africa, and seasonal and annual patterns in the time of sightings, as well as the number of postings, from southern Africa over a 10-year period, from 2010 to 2019 using Facebook and Instagram social media images.

(22%), autumn (17%), and summer (14%). Pangolin posts were also most common in winter (38%), followed by spring (27%), autumn (19%), and summer (16%). About half (53%) of all the observations of aardvarks were during the day—for pangolins, 26% of all posts were in the day (Supplementary Data SD1). Assessment of the time of sighting by season revealed that

aardvarks were seen mainly in the night, except in winter when most sightings were in the afternoon (Fig. 1). In contrast, there were no clear differences with season in the times of pangolin observations. (Fig. 1).

There were no clear long-term patterns in the time of day for Aardvark or pangolin observations. Aardvarks were seen most at night in 2014 (excludes 2010 when there was only 1 post made), while pangolin observations were rarely made at night in 2012.

From the 481 images and videos that were suitable for rating aardvark body condition, 306 aardvarks (64%) were in "good condition." Just over half (268) were captured when it was daytime. There was a strong association between time of day and body condition, such that an animal in poor body condition was more likely to be observed during the day (odds ratio [95% CI]: 0.08 [0.05; 0.13], $z = -9.63$, $P < 0.001$; Fig. 2).

There were 32 records of aardvarks drinking water across all months except December (Fig. 3). There were 7 posts of ground pangolins drinking, mostly in the warmer months (Fig. 3).

Predation was observed at almost all times of the year for both species. Aardvarks and ground pangolins were preyed on by spotted hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*), and lions (*Panthera leo*)—with leopards being the most common predator for aardvarks (84%), and lions the most common predator for ground pangolins (79%; Fig. 3).

Discussion

Social media provides supplementary information on 2 elusive mammals. The images of aardvarks ($n = 571$) and ground pangolins ($n = 673$) in South Africa confirm that aardvarks are found throughout South Africa while ground pangolins are restricted to the northern regions. There were far fewer records for other southern African countries, making it difficult to draw conclusions about distribution in those areas. In terms of the time of day of observations, ground pangolins were more commonly seen in the daytime than at nighttime across all seasons. In comparison, aardvarks were more likely to be seen at night, except in winter when daytime observations were more common. Changes in the time of observations over 24 h across different years are difficult to compare because of an increase in the number of observations posted on social media for both species, particularly from 2010 to 2016. However, changes in the relative number of observations at night and in the day between years may reflect changing environmental conditions, given that aardvarks in poor body condition were seen more often in daylight, whereas those in good condition were seen more often at night. Social media provide records of rarely observed drinking and predation for aardvarks and ground pangolins, and in our data set, leopards are the main predator for aardvarks, while lions are the main predator for ground pangolins.

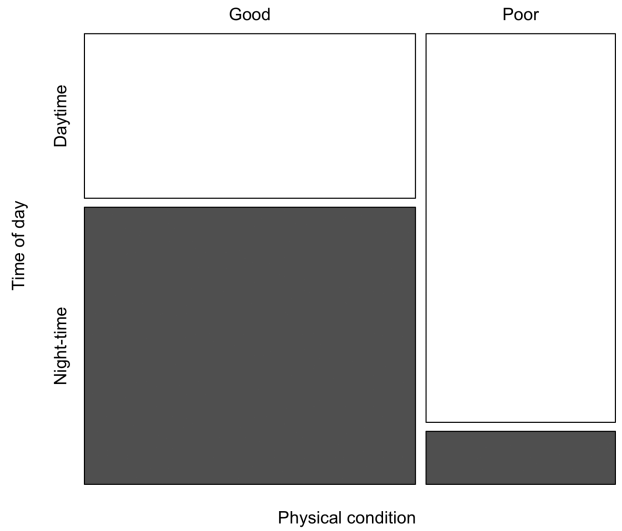

Fig. 2. The relationship between Aardvark body conditions and the time of day. There was a strong association between the time of day and body condition of the observed animal, such that aardvarks in poor body condition were seen more often in daylight, while those in good body condition were observed more often at night.

The major potential limitation in drawing inferences from our data set is that it is influenced by human behavior. An area such as the Kalahari is known to be favorable for observing ground pangolins and aardvarks, so increased ecotourism to that area for those sightings may bias the distribution counts. Similarly, the activity patterns of guests will influence the time of observations, across seasons and the 24-h day. For example, at Tswalu Kalahari Reserve, where many observations of both species were obtained (Supplementary Data SD1), guests are more likely to undertake early morning (04:30 to 09:00) and late afternoon (17:30 to 22:00) game drives in the hot summer, and day game drives (06:30 to 17:00) in the cooler winter with only occasional night drives (Prince Ngomane, Tswalu Kalahari Reserve, personal communication). Changing patterns across years are also difficult to interpret because the number of social media users, and therefore the likelihood of posted social media observations, has been increasing in recent years. We did find an increasing number of posts over time, with a relatively low number of posts from 2010 to 2015 (Tables 7 and 19, Supplementary Data SD1).

For example, the number of users of the popular Facebook page "Kruger Sightings" continued to increase across our 10-year data collection period (Supplementary Data SD1). Tourist seasonality and the size of the tourism industry also would need to be considered when using social media records to draw inferences from seasonal or annual changes in species numbers, distributions, or activity. Camera trap images of aardvarks, which comprised 22% of the total records that we found on social media, can provide continuous monitoring across the day and year, but require significant investment to cover the same regions as those explored by tourists, as well as image processing to identify species.

Despite the potential biases introduced by changing tourist and social media activity, the records we obtained confirm the known distributions for aardvarks and ground pangolins and provide a substantial increase in the number of records available for each species (Taylor et al. 2016; Pietersen et al. 2021). Most records of aardvarks and ground pangolins are largely confined to protected areas and their distribution is determined by the availability and suitability of ant and termite species, and soil that is conducive to digging burrows (Pietersen et al. 2016; Taylor et al. 2016). Our findings confirm previous reports that ground pangolins do not extend to the southern part of the country and are likely to be extirpated in the Free State, where the last record was in 1985 (Lynch 1975, 1983). It is thought that overexploitation and habitat loss have reduced populations in the Free State, Eastern Cape, and KwaZulu-Natal (Pietersen et al. 2014b, 2020). Historically, however, ground pangolins have been found in KwaZulu-Natal and they are currently being reintroduced into the province (Pietersen et al. 2014a; Murray 2015).

Social media data on Flickr and Twitter have been used before to draw inferences about the distribution of pangolins (Di Minin and Hausmann 2020). Geotagged posts confirmed the presence of

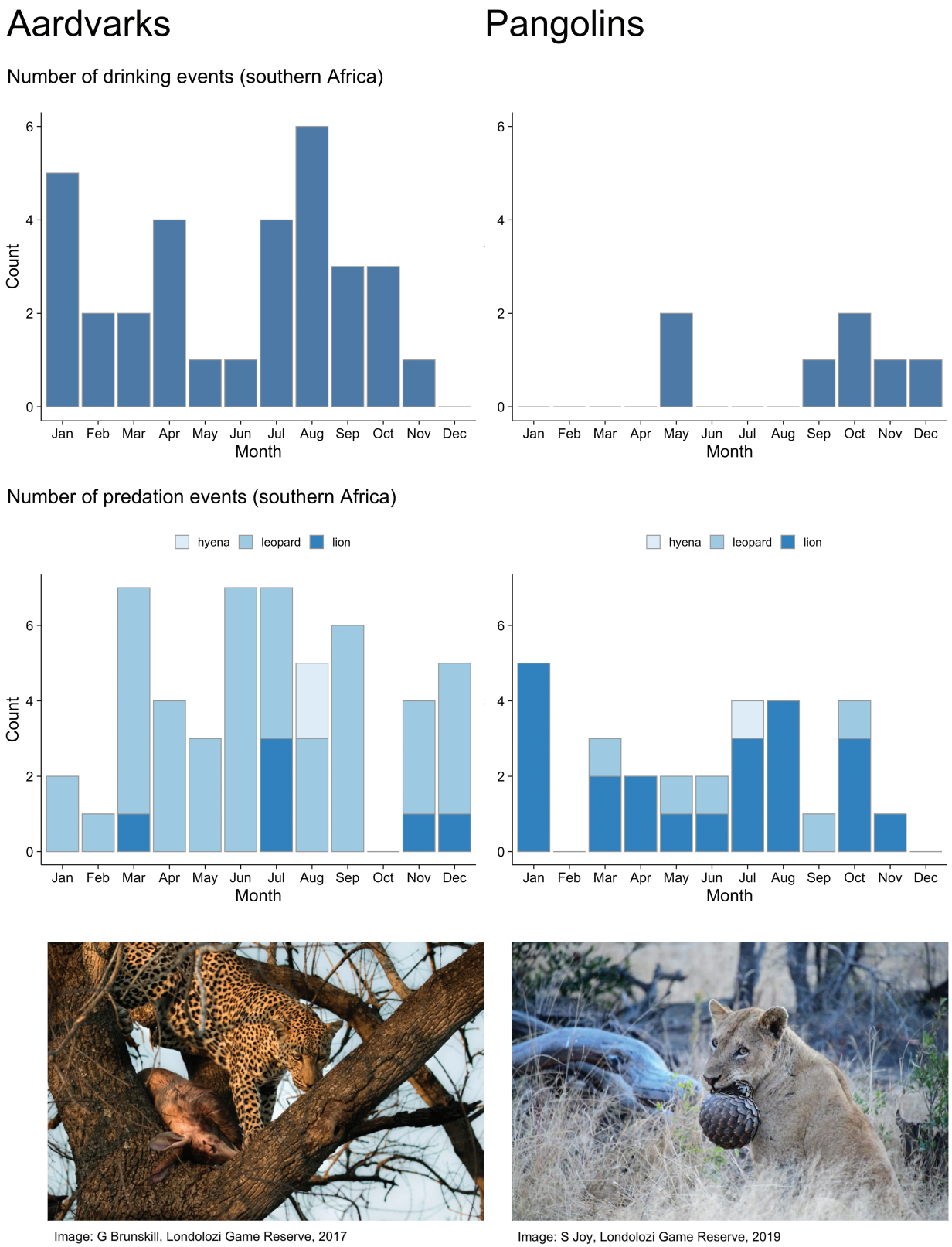

Fig. 3. The number of drinking and predation events of aardvarks (left) and ground pangolins (right), and example images of predation by a leopard on an aardvark, and a lion on a ground pangolin, from Londolozi Game Reserve in South Africa.

pangolins in 41 out of 54 countries in Africa and Asia, within the known IUCN geographic ranges. Facebook, the social media network with the most active users worldwide and the most popular for nature-related posts (Di Minin et al. 2015), has also been used to quantify media activity and public interest in pangolins and the pangolin trade (Harrington et al. 2018). One concern with accessing geotagged posts of pangolins is the risk of disclosing their location to potential poachers (Di Minin and Hausmann 2020).

While our distribution records based on social media posts may be biased by tourist behavior and camera trap placement, data extracted from social media can outperform other citizen science image-based approaches, such as iNaturalist and Google images (Maritz and Maritz 2020), and traditional data collection (Sullivan et al. 2019). At the time of writing, iNaturalist had 298 records for aardvarks and 38 for ground pangolins from southern Africa, far fewer than our sample. Some records provide only indirect evidence of aardvarks and pangolins (e.g. an aardvark burrow, image observed June 2016, Benfontein Nature Reserve), and some of those are incorrect (tracks incorrectly labeled as being ground pangolin tracks, image observed December 2014, Sofala Mozambique). Inspection of those records also reveals errors (e.g. an image of a Leopard Tortoise (*Stigmochelys pardalis*) is labeled as an Aardvark (image observed June 2016, Benfontein Nature Reserve), and animal tracks incorrectly labeled as being ground pangolin tracks (image observed December 2014, Sofala Mozambique). Camera trap images likely offer better insights into phenology and can reveal unusual animal behavior (Pardo et al. 2021) without the potential disturbance by human observers.

In terms of activity patterns, we expected that aardvarks and ground pangolins would be observed more often at night than in the day, as both species are nocturnal (Taylor and Skinner 2003). Aardvarks were seen more often at night, except in winter (Fig. 1). Diurnal activity has previously been shown to be more common for aardvarks in winter than in other seasons (Taylor and Skinner 2003; Rey et al. 2017; Weyer et al. 2020), and appears to be a response to lower ant and termite availability rather than avoidance of cold (Weyer et al. 2020). Indeed, aardvarks in the Kalahari that were in poor body condition basked in the sun in the morning outside burrows, presumably to increase their body temperature through an exogenous energy source (Weyer 2018). We hypothesized that aardvarks in poor body condition would be more likely to be seen in daylight, while those in good condition would be seen more often at night, and our data were consistent with that hypothesis (Fig. 2). Aardvarks that were in poor body condition succumbed to apparent starvation in drought periods and may be threatened by increasing drying associated with climate change (Rey et al. 2017; Weyer et al. 2020)—the continued monitoring of the timing of aardvark sightings may provide a useful tool for detecting the potential threat of climate change to aardvark survival.

Aardvarks and pangolins feed predominantly on ants and termites (Du Toit et al. 2014; Pietersen et al. 2016; Chao et al. 2020) and are more likely to emerge from their burrows earlier in the day in the face of reduced food availability (Panaino 2021). We did not detect a seasonal change in the pattern of timing of activity through social media images of ground pangolins, and only about a quarter of the images were taken at night, across all seasons (Fig. 1). A likely explanation for our unexpected finding of more diurnal observations may be the difficulty of observing pangolins at night, given their much smaller size relative to aardvarks.

In addition to food energy, aardvarks and ground pangolins are thought to obtain their water requirements mainly from their prey (Taylor and Skinner 2004; Pietersen et al. 2016; Taylor et al. 2016). Ground pangolins are reported to rarely drink free-standing water (Pietersen 2013; Challender et al. 2019; Panaino 2021) and only 7 records of aardvarks drinking water for the Karoo have been documented (Taylor and Skinner 2004; Skinner and Chimimba 2005; Kerley and Tompkins 2017). One advantage of mining social media data are insights of rare behavior, such as drinking. We obtained what we believe is the largest published data set of drinking for aardvarks (n = 32) and ground pangolins (n = 7; Fig. 3). It is possible that both species may become more reliant on drinking water when they face higher heat loads in summer. Drinking may also occur more often when food is scarce (and hence, reduced water intake through food; Weyer 2018). Kerley and Tompkins (2017) published 3 images of aardvarks drinking, and all aardvarks in those images would be scored as being in poor condition using our scoring system. Of the 32 drinking images that we obtained for aardvarks, 25 were suitable for body condition scoring, with 44% of those aardvarks rated as being in poor condition (overall 36% of the aardvarks assessed in our study were in poor condition). Ongoing collection of images revealing drinking episodes, particularly through camera traps placed at waterholes, would be useful in elucidating the importance of free-standing water in the ecophysiology of myrmecophagous mammals.

In addition to drinking behavior, our image collection also provides insights on the predation of aardvarks and ground pangolins. We obtained evidence of predation events in almost all months, with no clear seasonal patterns (Fig. 3). Previous studies have recorded African lions, leopards, hyenas, and honey badgers (*Mellivora capensis*) as predators of pangolins, although scales protecting pangolins make them hard to penetrate and kill (Swart 2013; Chao et al. 2020; Pietersen et al. 2020). Leopards, lions, spotted hyenas, cheetahs (*Acinonyx jubata*), wild dogs (*Lycaon pictus*), and pythons (*Python sebae*) have been observed preying on aardvarks (Bothma and Riche 1984; Kingdon 1997; Radloff and Du Toit 2004; Hayward et al. 2006; Williams et al. 2018). Aardvarks have been identified as one of the preferred prey items for lions in South Africa (Eloff 1973; Power 2002; Roxburgh 2010). However, a systematic literature survey of the diet of lions across their distribution range, with data on prey availability, revealed only 1 study with aardvark recorded as a potential prey item, with no available data for pangolins (Hayward et al. 2005). A similar analysis for leopards revealed 3 studies documenting Aardvark as a potential prey item, and only 1 documenting pangolin (Hayward et al. 2006). From the images we obtained, leopards appear to be the main predator (84%) for aardvarks, while pangolins appear to be targeted mostly by lions (79% of predation images). It could be argued that the behavior of leopards in hanging their prey in trees increases the likelihood that aardvark predation by leopards would be more readily observed, relative to that for lions. However, in most regions of southern Africa, it is much more likely that lions rather than leopards are observed by tourists (Maciejewski and Kerley 2014; Grünewald et al. 2016). The finding that the lion appears to be the main predator for pangolins is similar to previous studies (Chao et al. 2020; Petersen et al. 2020).

Further data on predation or drinking behavior for myrmecophagous mammals, or indeed any other behaviors or interactions of interest, could be solicited through the targeted sourcing of images (e.g. Maritz and Maritz 2020). That initiative provided more than 1,900 independent feeding observations posted on Facebook, involving 83 families of predators and 129 families of prey. Relative to a literature review spanning 226 sources and 138 years, the authors found that social media provided dietary records for snakes at greater speed and a finer taxonomic resolution, and revealed novel interactions (Maritz and Maritz 2020).

In summary, our extraction of social media images reveals the potential to obtain supplementary and novel information on the distribution and ecology of elusive species such as the Aardvark and ground pangolin. Social media can be used to monitor the occurrence of species in various locations, but whether it can be useful in tracking changing population numbers over time, and

therefore assist with conservation efforts, may be dependent on the number of social media users, and the number of posts plateauing. The increase in the number of sightings of aardvarks and ground pangolins from 2010 to 2019 in our data set likely reflects increasing numbers of Facebook and Instagram users in the country (World Wide Worx 2016; Statista 2020). More people in South Africa use social media as compared to other southern African countries (World Wide Worx 2016; Budree et al. 2019; Statista 2020), so social media data may be less useful in countries with lower user numbers, or countries that are less attractive as tourist destinations. Nevertheless, particularly as automated methods are available to extract data from social media, we believe that it can be a useful tool for gathering information on data-deficient species.

Supplementary data

Supplementary data are available at *Journal of Mammalogy* online.

Supplementary Data SD1.—Social media search terms, and additional summary data for each species.

Supplementary Data SD2.—Links for Aardvark social media images.

Supplementary Data SD3.—Links for Temminck's Ground Pangolin social media images.

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Author contributions

MVP and AF conceptualized the study, analyzed and collected the data, and wrote the paper. PRK analyzed the data and edited the paper. SKM edited the paper. LCRM and NMW analyzed body condition images and edited the paper.

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Conflict of interest

None declared.

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