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Erythristic leopards *Panthera pardus* in South Africa

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Background: Leopards (*Panthera pardus*) show genetically determined colour variation. Erythristic (strawberry) morphs, where individuals are paler and black pigment in the coat is replaced by a red-brown colour, are exceptionally rare in the wild. Historically, few records exist, with only five putative records known from India.

Objectives: To record the presence of erythristic leopards in our study site (Thaba Tholo Wilderness Reserve, Mpumalanga) and to collate records from across South Africa.

Method: A network of camera traps was used to record individual leopards at Thaba Tholo. We also surveyed local experts, searched the popular South African press, and used social media to request observations.

Results: Two out of 28 individual leopards (7.1%) recorded in our study site over 3 years were of this colour morph. We obtained records of five other erythristic leopards in the North West and Mpumalanga regions, with no reports outside of this population.

Conclusions: Erythristic leopards are widely dispersed across north-east South Africa, predominantly in the Lydenburg region, Mpumalanga. The presence of this rare colour morph may reflect the consequences of population fragmentation.

Introduction

There is a high degree of coat colour variation between geographic populations of leopards (*Panthera pardus* L., Carnivora: Felidae) (Kingdon *et al.* 2013). Individuals from arid regions are generally pale with dispersed and open-centred rosettes, in contrast to those residing in forests which are darker with clustered and small-centred rosettes. These patterns are thought to correspond with differing vegetation types and light levels in order to conceal the animal from prey and possibly other predators (Allen *et al.* 2010; Kingdon *et al.* 2013). This adaptive explanation is supported by the frequent occurrence of melanistic leopards in humid habitats such as the Malayan peninsula (Kawanishi *et al.* 2010; Schneider *et al.* 2012). The frequency of 'black panthers' dramatically decreases across more arid regions (Kawanishi *et al.* 2010). The release of eumelanin (black pigmentation) into mammalian pelage is known to be regulated by the *extension* gene and phaeomelanin (yellow-red pigmentation) by the *agouti* gene (Fontanesi *et al*. 2009). Mutations to either of these genes can produce melanism in felids; however, it is a mutation in the *agouti* gene which results in melanism in leopards which is inherited as a recessive trait (Schneider *et al.* 2012).

In contrast, extreme pale (albino) colour morphs, which lack any pigmentation, or erythrism, which contain red pigmentation instead of black, are rarely documented in wild leopards (Divyabhanusinh 1993; Hartwell 2015; Sunquist & Sunquist 2014). Although the cause of erythrism in large felines is unknown, Peterschmitt *et al.* (2009) found evidence for a recessive mutation in the *extension* gene which produces more phaeomelanin, resulting in an amber colour in the domestic Norwegian Forest Cat (*Felis catus*). Similar mutations may also be responsible for the red colouration seen in dogs, humans, and other mammals (Fontanesi *et al.* 2009; Majerus & Mundy 2003).

Reports of erythristic leopards (also informally known as strawberry or red leopards, or pink panthers; Anonymous 2013, 2014a, 2015; Dell'Amore 2012) are exceptionally rare. A detailed search of the literature found only one paper (Divyabhanusinh 1993) which reported that five pale leopards with light brown spots (one male, one female, and the rest undetermined) had been shot in India between 1905 and 1965. To our knowledge, no other records of wild erythristic leopards were documented until 2012 when a male was photographed by a guide at the Madikwe Game

Reserve in the North West Province of South Africa (Figure 1). This was subsequently reported in the popular press (Dell'Amore 2012). Here, we report new sightings from Mpumalanga and the results of a survey of managers and section rangers of National Parks, wildlife reserves, and conservation organisations in South Africa, supplemented by press reports and social media, to understand the possible distribution and abundance of this leopard colour morph.

Methods

Our study

Original images were taken by camera traps as part of a wider study conducted at Thaba Tholo Wilderness Reserve (TTWR, Latitude: 24°57"404 S, Longitude: 30°21"105 E, Figure 1), Mpumalanga, South Africa, c. 20 km north-west of Lydenburg. TTWR is 5400 ha in area and is situated between the Steenkampsberg and Mauchsberg mountain ranges. The reserve lies on the boundary of two major biomes formally classified as savannah in the valleys and northern section of the reserve, and grassland on top of the mountains in the southern section of the reserve (Pirie, Thomas & Fellowes 2016). Altitudes range between 1100 m and 2000 m and the reserve has an average annual summer rainfall of 700 mm – 900 mm falling mainly between October and February.

Leopard presence at TTWR was recorded using a network of more than 30 camera trap sites positioned less than 2.7 km apart, based on a grid system; sites were chosen to maximise the likelihood of recording leopards and covered all regions. Little Acorn 5210A (Ltl Acorn, Green Bay, Wisconsin, USA) camera units were used, which had three heat and motion sensors which could be triggered up to 15 m away. A series of three images were taken per trigger, with a 30-second interval between captures. The cameras had been in place for 3 years in October 2012.

Wider survey

Twenty-five appropriate representatives from South African National Parks, the Endangered Wildlife Trust, Panthera, and similar organisations and reserves across South Africa were contacted via e-mail and asked if they have had reports of erythristic/strawberry leopards. A request was made to reply even if no animal had been witnessed. Other reports, including press, were located using Web of Science (http://www.wos.com), Google (http://www.google.co.uk), and references from Hartwell (2015). A general request was also posted on Twitter using the #mammalwatching hashtag, where it was seen 3077 times at the time of writing.

Results

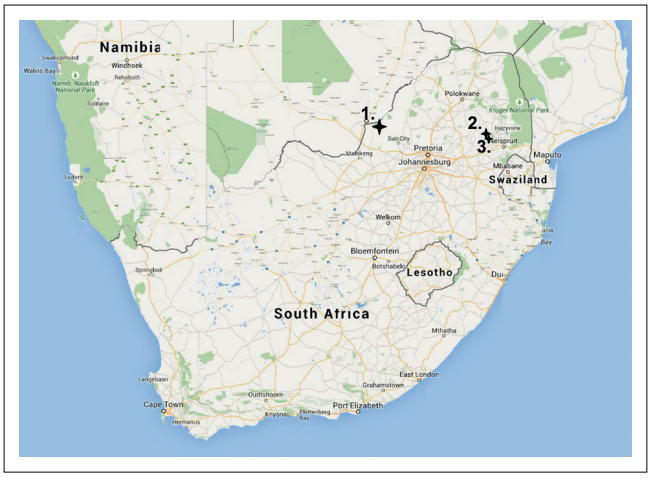
From the Internet search and local reports, five individual erythristic leopards, identified through pelage patterns have been captured on camera trap, killed, or caught, in the Lydenburg area, Mpumalanga; and two animals in Madikwe Game Reserve and the surrounding area, North West Province (Figure 1, Table 1). Of the 28 individual leopards recorded at TTWR during this 3-year study, two (7.14%) were erythristic (Figures 2, 3a and b); one of these was born to a normal coloured female (Figure 3a and b).

Of the 25 individuals approached we received replies from 19 managers, section rangers, and researchers from reserves and organisations from across South Africa. The skin of one other erythristic animal (Table 1: animal 1) was provided as evidence. No other responses were received from the social media call for information on strawberry leopard sightings.

Discussion

To our knowledge, only one previous paper has reported the presence of erythristic leopards (in India; Divyabhanusinh 1993). Here, we provide the first formal report of the presence of wild erythristic leopards outside of India. In total, there are seven records of wild erythristic leopards in South Africa, five in the Lydenburg area.

South Africa's first erythristic leopard report in 2012 was recorded in the North West Province, some 400 km from our

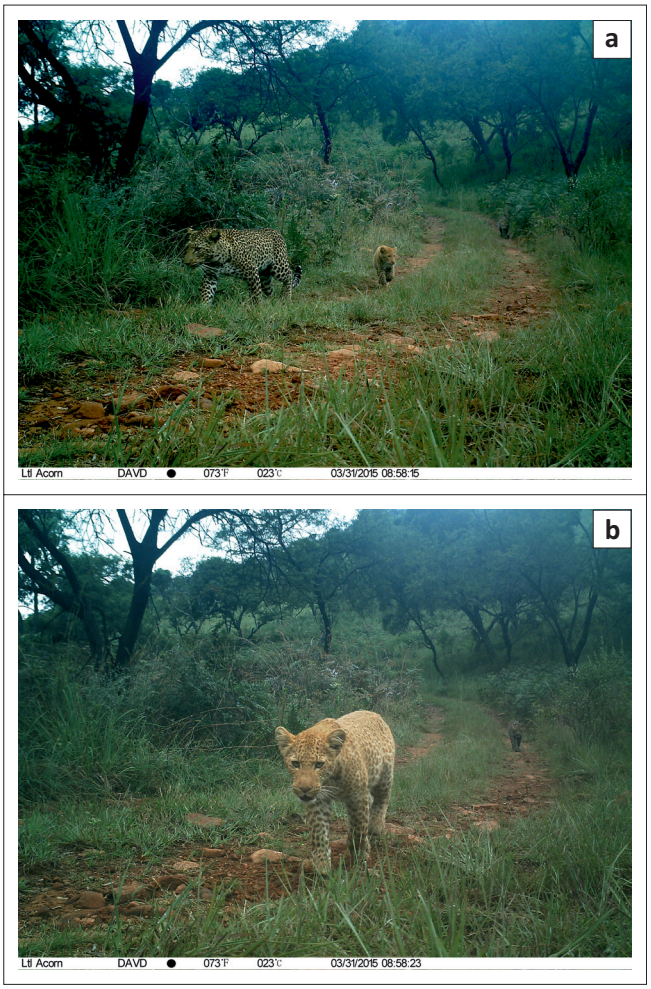


Source: Google Street Map downloaded 02-07-2015 in QGIS 2015

FIGURE 1: Map of South Africa with relative locations of (1) Madikwe Game Reserve, North West Province, (2) Thaba Tholo Wilderness Reserve, Mpumalanga, and (3) Lydenburg, Mpumalanga.

Source: Ingwe Leopard Research

FIGURE 2: Image of erythristic individual 5 taken on a property on the R37 outside Lydenburg, Mpumalanga, Latitude: 24°93310 S Longitude: 30°33716 E, 01 May 2015.



Source: Ingwe Leopard Research

FIGURE 3: (a) First in a series of three images of an adult female leopard, FS44 left, and her erythristic cub (animal 7), middle, taken on 31 March 2015 at Thaba Tholo Wilderness Reserve, Latitude: 24°98322 S Longitude: 30°35086 E; (b) last image in the series taken on 31 March 2015 at TTWR of FS44's erythristic cub (centre frame of image) and the second normal coloured cub (far right of image).

Mpumalanga study site. Although such distances are likely to preclude dispersal of offspring of any given individual, it has been suggested that these widely separated leopard populations may be considered part of a single core population (Friedmann & Traylor-Holzer 2008).

General colour resemblance (where an animal resembles the general colour of their environment) may be the reason for the higher frequency of melanistic leopards in moist habitats sporting thick vegetation (Allen *et al.* 2010), but this is unlikely to provide an explanation for the presence of the erythristic forms recorded here, as this region does not exhibit a prolonged dry season and leopards in savannah habitats are thought to be predominantly nocturnal hunters (Bailey 1993), hence a pale pelage would not be beneficial.

It is worth considering other explanations for the recent sightings of erythristic leopards in Mpumalanga, and we posit three hypotheses. Firstly, this is simply a reflection of reporting bias. The area covered by the camera traps is limited and although our reports are unlikely to present a precise density of this colour morph, the numbers of observers and sightings consulted though social media from large National Parks to smallholdings across South Africa are a good indication of its rarity. Therefore we feel that reporting bias is unlikely (although because of the secretive nature of leopards, it is possible that unusual behaviours or forms are overlooked, e.g. Pirie *et al*. 2014). Secondly, and highly speculatively, this may reflect leopards released or escaping from captive breeding programmes, where animals are reared for trophy hunting. Some nine game ranches in South Africa breed leopard (Lindsey *et al.* 2011) and the captive breeding of colour morphs of other species for hunting, such as lion (*Panthera leo*), is known to occur (Crowley 2015). Indeed, there is a record of a captive bred male strawberry leopard born to parents which came from the same area as the wild individual seen in 2012 (Anonymous 2014a). This is possible, but unsubstantiated. Thirdly, population fragmentation and isolation and therefore a highly reduced effective population size, may have resulted in the expression of a *de novo* or previously rare allele at higher frequencies. Such inbreeding effects are thought to result in the presence of the very rare king cheetah (*Acinonyx jubatus*) and white lion colour morphs in southern Africa (Sunquist & Sunquist 2014); it has also been documented with leopards in the Malaysian peninsula, where the rapid near fixation of melanism occurred following population fragmentation (Hedges *et al*. 2015; Kawanishi *et al*. 2010). Similarly, Haag *et al*. (2010) reported genetic drift within small fragmented jaguar populations over a relatively short time frame and McManus *et al.* (2015) showed that leopard populations can become isolated within a few generations. Perhaps this is the most reasonable explanation for observing the erythristic morph in relatively high numbers in a single area; however we can only speculate, and future research is required to test this explanation.

The geographical range of the leopard has diminished by an estimated 37%, which underpinned the need to reclassify the leopard on the International Union for Conservation of Nature (IUCN) (Red data list from least concern to near-threatened in 2008 (Balme, Slotow & Hunter 2010). Within South Africa, the destruction of suitable leopard habitat has produced highly fragmented areas with depleted prey densities, (Chase-Grey 2011; Swanepoel *et al.* 2013) which combined with persecution (Lindsey *et al*. 2011) has substantially reduced leopard numbers and caused populations to become isolated (Friedmann & Traylor-Holzer 2008). Until January 2016, 150 CITES (Convention for the International Trade in Endangered Species) trophy animal permits were allocated annually to South Africa (Balme *et al.* 2010; Lindsey *et al*. 2011). Zero permits have been allocated for 2016; however, this is temporary and will be reassessed for 2017 (Anonymous 2016). Documenting this rare leopard colour morph could result in negative outcomes (e.g. encouraging illegal capture for breeding); however, the expression of erythrism could be a visible indicator which highlights the consequences of population fragmentation and decline.

TABLE 1: All reports found of erythristic leopards in South Africa.

Animal	Date	Age and sex	Location	How recorded	Reference	Notes
1	Unknown > 20 years ago	Unknown sex	Close to Botswanan border and Madikwe Game Reserve	Shot	Anonymous (pers. comm., 15 Oct 2015)	Skin given to a farmer in Lydenburg Area
2	Aug-05	Adult female	R36, Lydenburg	Carcass; road death	Mr. B Van der Wal (pers. comm., 22 Oct 2015)	-
3	2012	Adult male	Madikwe Game Reserve Latitude: 24°8167 S Longitude: 26°2167 E	Photographed	Dell' Amore 2012	Photographed by Deon De Villiers
	Sept-15	-		Camera trap images	Samantha Sealie, Madikwe Conservancy Private Game Reserve; Gareth Mann, Panthera	-
4	Mar-13	Adult female	Sekhukhune road, Lydenburg	Carcass; road death	Anonymous 2013	Had recently weaned cubs
5 or 6	Jan-14	Unknown	Lydenburg area	Photographed	Driene Nortje (pers. comm., 08 Oct 2015)	Probably animal 5 or 6
5	Sept-14 (x3)	Adult female	Thaba Tholo Wilderness Reserve Latitude: 24°98322 S Longitude: 30°35086 E and surrounding properties Latitude: 24°93310 S Longitude: 30°33716 E	Camera trap images (Figure 2)	This study	Pictured with known male
	Oct-14	-		-	-	-
	Jan-15	-		-	-	-
	Feb-15 (x2)	-		-	-	-
	May-15	-		-	-	-
6	Nov-14	Two-year-old male	Lydenburg area	Photographed; later captured and released	Anonymous 2014b	Satellite collared by Mpumalanga Tourism and Parks Authority
	Jan-15	-		-	Anonymous 2015	-
7	Mar-15	Unweaned cub	Thaba Tholo Wilderness Reserve Latitude: 24°98322 S Longitude: 30°35086 E	Camera trap images (Figure 3)	This study	With mother (normal coloured mother and grandmother)
	May-15	-		-	-	-
	Jun-15	-		-	-	-
	Jul-15	-		Observed by field worker	-	-

Conclusion

We collated seven records of erythristic leopards in South Africa. Two of 28 individuals recorded at our study site (Thabo Tholo Wilderness Reserve; Mpumalanga) were of this form, and we found five other records from Mpumalanga and North West provinces. The majority of records were recent, and the oldest was from the late 1990s we were unable to find earlier records of erythristic leopards from South Africa. Although speculative, we suggest that this may reflect the consequences of increased population fragmentation and consequent inbreeding. Further research is needed in order to ascertain whether erythristic leopards are a visible sign of increasing threats to the viability of local leopard populations.

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

T.J.P., R.L.T. and M.D.E.F. generated the idea for the paper. T.J.P. collated data and T.J.P., R.L.T. and M.D.E.F. wrote the article.

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