A review of the anthropogenic threats faced by Temminck's ground pangolin, *Smutsia temminckii*, in southern Africa

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Throughout its range, Temminck's ground pangolin, *Smutsia temminckii*, is becoming increasingly threatened, predominantly as a result of anthropogenic pressures. This species is currently listed as *Vulnerable* in South Africa and *Least Concern* globally, although many assessment criteria are data deficient and thus hamper an accurate assessment of its actual status. Current knowledge of the threats faced by Temminck's ground pangolin largely stem from a handful of ecological studies and *ad hoc* observations. Here we synthesize data on the known threats faced by this species in southern Africa and highlight a number of new threats not previously recognized. The main threats faced by this species include electrocution on electrified fences, the traditional medicine (*muthi*) trade, habitat loss, road mortalities, capture in gin traps, and potentially poisoning. Electrocutions arguably pose the greatest threat and mortality rates may be as high as one individual per 11 km of electrified fence per year. However, the magnitude of the threat posed by the *muthi* trade has not yet been quantified. Most southern African countries have adequate legislation protecting this species, although implementation is often lacking and in some instances the imposed penalties are unlikely to be a deterrent. We propose mitigating actions for many of the identified threats, although further research into the efficacy of these actions, and the development of additional mitigating procedures, is required.

Key words: *Smutsia temminckii*, *Manis temminckii*, electrocutions, traditional medicine, international trade, legislation, mitigation.

INTRODUCTION

Temminck's ground pangolin, *Smutsia temminckii*, (hereafter referred to as 'pangolin') is an elusive, poorly-studied mammal that inhabits savannas and woodlands of southern and East Africa. It ranges from northern South Africa through southern and East Africa, reaching its northern limits in southern Sudan and southern Chad (Hoffmann 2008; Swart 2013). The dorsal and lateral surfaces are covered in overlapping hard, plate-like scales (Smithers 1983) which afford them protection from most predators and renders them easily distinguishable from other mammals. When threatened, a pangolin rolls into a tight ball with the vulnerable head and soft underbelly covered by the broad, muscular tail, thus presenting the attacker with a nearly impenetrable barrier of armour (Kingdon 1971; Smithers 1971, 1983; Heath 1992; Richer *et al.* 1997; Heath & Coulson 1998; Swart 2013).

Due to the secretive nature and low population densities of this species (Pietersen 2013; Swart 2013), relatively little is known about the threats that it faces. However, it is known that all pangolin species (Manidae) are widely revered for their traditional healing powers (Kingdon 1971; Coulson 1989; Heath 1992; Bräutigam *et al.* 1994; Swart 1996; Heath & Coulson 1997; Kyle 2000; Friedmann & Daly 2004; Soewu & Ayodele 2009; Manwa & Ndamba 2011; Soewu & Adekanola 2011; Whiting *et al.* 2011) and are also utilized as a source of protein (van Aarde *et al.* 1990; Ansell 1960; Kingdon 1971; Fa *et al.* 1995, 2002; Willcox & Nambu 2007). Electrified game fences are also known to pose a threat to pangolins (van Aarde *et al.* 1990; Friedmann & Daly 2004; Beck 2008) while other previously identified threats include

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habitat destruction (Coulson 1989; Friedmann & Daly 2004), road mortalities (Coulson 1989) and a high susceptibility to toxic chemicals (van Ee 1966, 1978; Heath 1992; Friedmann & Daly 2004). Bräutigam *et al*. (1994) also mention the threat posed by the illicit export of pangolins for the Asian cuisine and traditional medicine markets, and recent studies suggest that this threat is steadily increasing (Challender 2011; Challender & Hywood 2012; IFAW 2013).

Pangolins are listed as *Vulnerable* in South Africa (Friedmann & Daly 2004), although most assessment parameters for this species are poorly known. Globally, this species is listed as *Least Concern* but the population is believed to be decreasing (Hoffmann 2008) and most assessment criteria are data deficient. Of the four African pangolin species, Temminck's ground pangolin has been studied most intensively, enabling us to review the known threats faced by this species. No comprehensive threat review has previously been undertaken for this species, with even the most recent IUCN Red List assessment (Hoffmann 2008) relying on limited data. Here we synthesize available literature pertaining to threats faced by pangolins in southern Africa, and highlight new threats which have recently come to light. We also present new empirical data, primarily regarding mortality associated with electric fences. This review is intended to facilitate future threat assessments for this species by providing a comprehensive dataset of the threats facing this species.

MATERIALS AND METHODS

Data on threats facing pangolins in southern Africa were extracted from all published literature making mention of this topic, with additional data being gathered during a four-year study of this species in the Kalahari Desert (Pietersen 2013). In the context of this article, southern Africa is defined as the area south of the Cunene and Zambezi rivers because all studies of pangolins to date (with the exclusion of Sweeney 1956) have been limited to this region.

Fence electrocution data were extracted from the records held by Kalahari Oryx Private Game Farm (KO), a 52 000 ha farm located at 28°30′S; 22°02′E in the southern Kalahari Desert in the Northern Cape province of South Africa. As part of KO's fence monitoring protocol, fences were monitored three times per week and all fence-related mortalities recorded. Data for the period 1 September 2009 to 31 August 2012 collected along a 93 km stretch of fence were used for mortality rate calculations, whereas electrocutions from the entire farm were used to infer age, sex and seasonal electrocution trends. The farm is fenced according to the Northern Cape Nature Conservation Act 9/2009 (NCNCA 9/2009) specifications for large predators, *viz.* a 2.4 m high, 21-strand game fence with wire mesh extending 950 mm up the fence and buried to a depth of 250 mm. There are six electrified live strands and five earth strands offset from the fence with insulated brackets, and a double-strand live-earth (inside) or single-strand live (outside) tripwire offset 500 mm from the fence and set at a height of 200 mm. It should be noted that the farm is fenced according to the specifications of the draft Northern Cape Nature Conservation Act, which requires a single live strand on the outside tripwire, whereas the updated NCNCA 9/2009 requires that both internal and external tripwires consist of an upper live and a lower earth strand.

Road mortalities were recorded during *ad hoc* monitoring of a 70 km stretch of the N14 national road between KO and the nearest town (Upington) at an average frequency of one trip every five days. Additional road mortalities were inferred from study skins present at KO that originated along a 15 km stretch of the N14 between 2003 and 2008.

THREATS

Electrified fences

Unlike most mammals, pangolins are bipedal, walking on their hind legs with the front legs and tail held off the ground, which results in their unprotected ventral surfaces being exposed. When a pangolin comes into contact with an electrified fence the head or underbelly usually receives the initial shock. This results in the animal adopting its defence of rolling into a ball, often inadvertently wrapping itself around the electrified wire in the process (D.W.P., pers. obs.). Once wrapped around the wire each successive shock causes the trapped animal to curl even tighter around the wire, until the repeated electrical pulses eventually kill it. Individuals found on electrified fences frequently display epidermal burns (including holes burnt through their scales), while internal injuries may also be significant (D.W.P., pers. obs.; E. Lane, unpubl. data). On occasions the electric pulses are too weak to kill an individual outright, but strong enough to evoke the defence response of remaining curled up in a ball (straddling the wires). In these instances individuals eventually succumb to exposure and/or starvation, but if found in time they can often be removed from the electrified fence and released unharmed. However, after prolonged exposure to the electric current individuals may develop debilitating, apparently neurological disorders and although these individuals may walk off after being removed from the fence, they do not move far before collapsing and ultimately dying from exposure and starvation (D.W.P., unpubl. data).

Various authors have raised concerns over the numbers of pangolins electrocuted on fences (van Aarde *et al.* 1990; Friedmann & Daly 2004; Beck 2008), although only Beck (2008) presented quantitative data on the prevalence of electrocutions. During a year-long study at Tswalu Kalahari Reserve in the Northern Cape Province, Beck (2008) recorded an electrocution rate of 0.033 individuals/km/year, or one pangolin electrocuted per year for every 30 km of electrified fence.

Between 1 September 2009 and 31 August 2012, 21 pangolins were found electrocuted on the 93 km fence at KO and an additional four individuals were removed from this fence and released alive. These data (including individuals that were found alive and removed but which would have died otherwise) indicate a mortality rate of 0.09 individuals/km/yr, substantially higher than the mortality rate recorded by Beck (2008). Of the 26 electrocutions for which sex data are available, 62% (n = 16) were male and 38% (n = 10) were female. These results suggest a slight male-biased fence mortality, which can be partially explained by the results of an ecological study undertaken at the same site (Pietersen 2013). The results of this study suggest that male pangolins reach sexual maturity later than females and also establish a fixed home range at a later age. Thus males traverse greater distances than do females before establishing a home range, and may travel further from their natal home range than do females (Pietersen 2013). Consequently males stand a greater chance of encountering an electrified fence.

Electrocutions are known to occur across this species' range in southern Africa (van Aarde *et al.* 1990; Friedmann & Daly 2004; Beck 2008; G. van Dyk, pers. comm.; P. White, pers. comm.; R. Els, pers. comm.; A.P.W.G., unpubl. data) as well as beyond the subregion (A.P.W.G., unpubl. data). Quantifying the numbers of individuals actually killed is difficult, as many of the vast conservation areas do not have regular fence patrols, there are a multitude of scavengers that may remove the carcass from the fence before it can be discovered by these monitoring teams, and owing to the traditional uses of this species, carcasses may be removed by the monitoring teams and sold to traditional healers or used themselves. Accurately determining the total length of electrified fences in southern Africa is also problematic. There is a general lack of data, while defining what actually constitutes an electrified fence is more difficult than it may first appear. Furthermore new fences are frequently erected while existing fences are removed as management practices change, land is purchased and agreements entered into, and political changes occur (Ferguson & Hanks 2010). Also, not all electrified fences are of similar design and even though a fence exists it may be dilapidated and functionally non-existent (Ferguson & Hanks 2010). With these limitations in mind, Botswana has an estimated 3000 km of fences while Namibia has an estimated 1100 km of fencing (Ferguson & Hanks 2010). No data are available for the proportion of these fences that are electrified, but considering that the majority of these fences are located around game farms and protected areas, it seems reasonable to assume that more than half of these fences are electrified. Thus using an estimate that 60% of these fences are electrified, this translates to approximately 1800 km of electrified fencing in these countries. Zimbabwe's electrified fences are largely non-functional or entirely removed and thus electrocution would not seem to pose a significant threat in that country. Likewise, Mozambique has a virtual total lack of electrified fences (D.W.P., pers. obs.). Of the southern African countries, South Africa has the largest extent of electrified fences falling within pangolin distribution and thus electrocutions are also most prevalent here, *e.g.* the Kruger National Park falls within one of the densest pangolin distributional ranges and it alone has close to 1000 km of electrified fences (Ferguson & Hanks 2010). Furthermore, many game reserves (both private and provincial) and National Parks are located within the distribution range of pangolins in South Africa. Pangolins occur across 21% of South Africa, coinciding with the greatest concentration of game farms (and livestock farms in the west) in the country (A.P.W.G., unpubl. data). There are an estimated 90 000 km of game fences in South Africa, excluding livestock fences (Beck

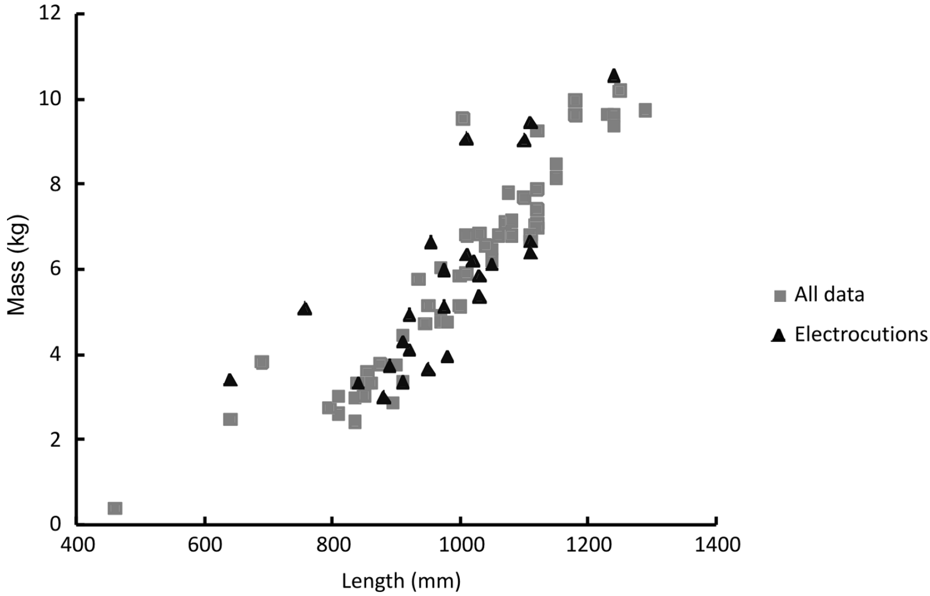

Fig. 1. Morphometric data for 25 pangolins found electrocuted at Kalahari Oryx Private Game Farm between September 2009 and August 2012, compared to the morphometric data for all pangolins recorded at this site.

2008). Assuming that these are equally distributed across South Africa there is an estimated 19 033 km of game fences overlapping the distribution of pangolins in South Africa. Again using an estimate that 60% of these fences are electrified, there are 11 420 km of electrified fences in South Africa posing a direct threat to pangolins (excluding livestock fences that may have an electrified strand). This equates to approximately 13 220 km of electrified fencing in southern Africa overlapping the distribution of pangolins. Beck (2008) reported a mortality rate of 0.033 pangolins/km/yr while this study recorded a mortality rate of 0.09 individuals/km/yr. Using these two electrocution rates it is conservatively estimated that between 436 and 1190 pangolins are electrocuted in southern Africa every year. The actual numbers may be higher due to some individuals going unrecorded, as well as the extent to which livestock fences are electrified not being known or considered in these calculations (see below).

The specifications for game fences stipulated in Provincial Nature Conservation Regulations depend on the type of game animals contained on a farm. In the Northern Cape, all fences for dangerous game include a two-strand offset tripwire on either side of the fence set at a height of 200 mm, and a lowest electrified strand on the main fence also set at a height of 200 mm above the ground (NCNCA 9/2009). There is also a growing trend amongst livestock farmers to place an electrified wire on either side of their livestock fences at a height of 100–300 mm in an attempt to prevent the two main livestock predators, *viz.* caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) (hereafter referred to as 'damage-causing predators') from gaining access to their farms (see also Beck 2008). The total length of electrified livestock fences is unknown and thus these fences were not included in the above estimates of annual mortalities.

An analysis of 25 electrocutions on KO for which reliable morphometric data are available indicates a higher proportion of mortalities in the 3.0–7.0 kg (840–1110 mm) size range (Fig. 1). There are two potential explanations: 1) this pattern represents the proportion of this size class in the greater population; and 2) individuals in this size class are juveniles and young adults and many (especially males) appear to be floaters, *i.e.* wandering over large distances in search of a vacant territory (Pietersen 2013). Larger (*i.e.* older) individuals tend to remain within a fixed home range that may or may not include an electrified fence and appear to recognize the threat posed by these barriers and are thus able to negotiate them safely. In one instance an adult female pangolin occupied a den site *c.* 50 m north of an electrified fence and would pass through a hole underneath this fence nightly to forage on the southern side before returning to

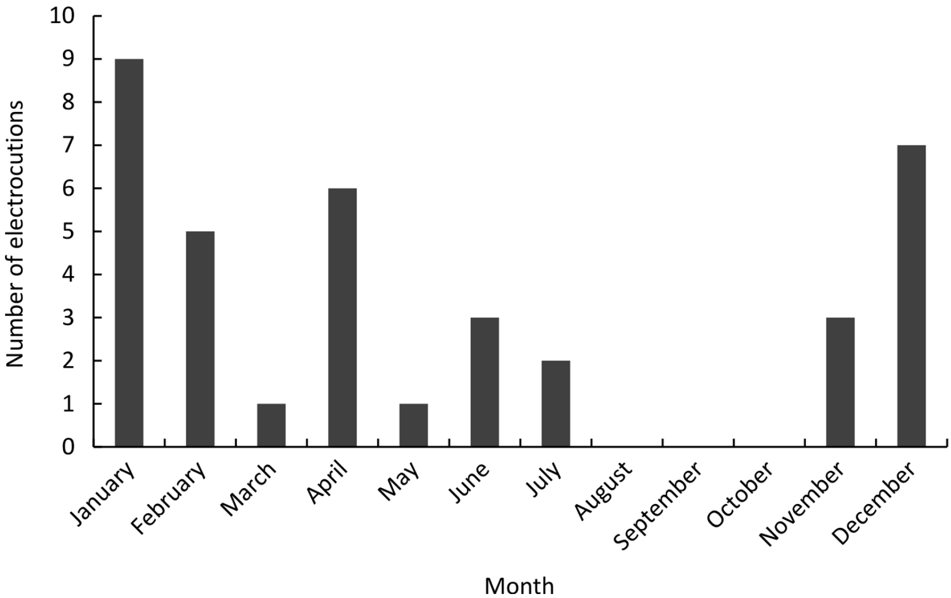

Fig. 2. Total numbers of pangolin electrocutions recorded between December 2007 and July 2012 on Kalahari Oryx Private Game Farm, shown per month.

the same den site to sleep. Thus she passed through the fence at least twice a night, with this situation continuing for at least two weeks (D.W.P., unpubl. data). Another adult female as well as three adult male pangolins that were tracked with radio telemetry frequently passed through electrified fences without any hindrance (Pietersen 2013). Tracks of adult individuals that were followed at the study site also indicate that many territorial adults frequently passed unhindered through electrified fences (D.W.P., unpubl. data).

There was a peak in electrocutions between January and April, while no electrocutions were recorded between August and October (Fig. 2). This summer peak coincides with a peak in rainfall and may reflect a period of greater activity and movement as this is also when the previous years' pups start dispersing (Pietersen 2013).

Fences *per se* do not pose a significant threat to pangolins or their movements, although occasional reports were received of pangolins becoming entangled and dying in mesh livestock fences. When a pangolin reaches a fence, it usually walks along this structure, periodically testing the fence for any weak spots through which it can pass and often covering a considerable distance in the process. Weak spots in fences usually take the form of a hole dug underneath the fence by another species or a locality where the fence has rusted through, the latter particularly with older fences. In the case of a non-electrified fence, pangolins may resort to climbing over this structure (Smithers 1971) and have been known to climb over fences in excess of 2 m in height (M. Booysen, pers. comm., 1 July 2011).

Traditional medicine, bushmeat trade and international trade

An additional threat faced by pangolins is their use for traditional medicine (*muthi*) and as a source of food (Ansell 1960; Kingdon 1971; Coulson 1989; Heath 1992, and references therein; Bräutigam *et al*. 1994; Heath & Coulson 1997). Throughout their range pangolins are revered for their perceived medicinal and magical powers and are also killed out of ignorance, as well as to obtain their scales for inclusion in traditional dresses and ornamentations (Kingdon 1971; Heath & Coulson 1997, and references therein; Kyle 2000; Soewu & Ayodele 2009; Manwa & Ndamba 2011). Nearly all parts of pangolins are used in *muthi* and ceremonies, including those intended to produce rain, seek favour from higher authorities and cure various ailments (Kingdon 1971; Heath & Coulson 1997, and references therein; Kyle 2000; Soewu & Ayodele 2009). Jacobsen *et al*. (1991) recorded three instances of pangolins being killed for food, while a fourth individual was shot for no apparent reason. In the Kalahari, many farm workers will eat pangolins that are found dead, although few pro-

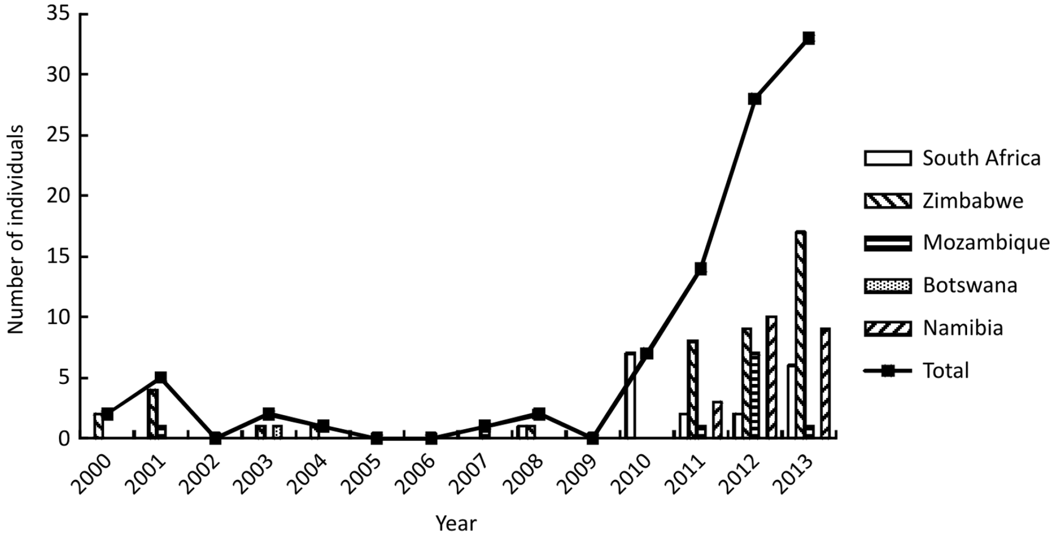

Fig. 3. Number of pangolin individuals confiscated in southern Africa between 1 January 2000 and 31 December 2013. An additional 15 individuals were confiscated in Namibia during this period, but the exact year(s) of confiscation are unknown and hence these seizures are not represented in this figure.

fess to actively seeking them as food. Older literature also suggests that pangolins were actively sought for food in eastern South Africa (Kirby 1896). The extent to which pangolins are being used in the local *muthi* trade and as a source of food has not yet been quantified, but it is known to be high in both the urban *muthi* markets and rural areas (R. Bruyns, pers. comm., 26 June 2011; A. Baiyewu, pers. comm., 26 June 2011). This species is now ecologically extinct in KwaZulu-Natal (Kyle 2000; Friedmann & Daly 2004; APWG, unpubl. data), an area that probably formerly supported a healthy population. It is believed that this rarity is largely due to direct persecution for *muthi* (Ngwenya 2001) and food, animals being removed from the wild and presented to tribal chiefs and statesmen as gifts, and to a lesser extent habitat loss.

There is also a growing tendency for pangolins to be exported to the Asian markets (Bräutigam *et al.* 1994; Challender 2011; Challender & Hywood 2012), which is likely to place an even greater strain on this species. Figure 3 indicates the number of pangolins confiscated from illicit trade between 1 January 2000 and 31 December 2013. These figures only reflect the individuals that were found and the actual number of animals traded is likely to be far greater due to the illegal, and therefore hidden, nature of this trade (Bräutigam *et al.* 1994; Broad *et al.* 2003; Challender & Hywood 2012). An additional 15 pangolins confiscated in Namibia between 2004 and 2013 are not reflected in these figures as the exact year of confiscation is not known. Furthermore, these figures do not represent animals in the *muthi* markets, as these markets are not regularly monitored and gaining access to some of the markets can be problematic. Although it is unknown whether the confiscated individuals reported on above were destined for local or international markets, the confiscation of a number of animals in up-market urban suburbs and harbours suggests that at least some of them were destined for international markets or consumption by foreigners now living in southern Africa. The rapid increase in reported trade since 2011 is believed to reflect a genuine increase in trade levels rather than greater awareness, as monitoring in most of these countries has been on-going for many years.

Temminck's ground pangolin is listed on CITES Appendix II with international trade permitted provided that a CITES permit has been issued and a Non-Detriment Finding (NDF) has been lodged for the species. A NDF is an objective study assessing whether the numbers of a species that are legally traded will have a negative impact on that species. In reality it is difficult to issue an NDF for a species such as Temminck's ground pangolin as their secretive nature makes estimating the total population size difficult, thus legal trade should in effect be limited. Temminck's ground pangolins are also protected by the national legislation

Table 1. Legislation governing activities pertaining to Temminck's ground pangolin, *Smutsia temminckii*, in southern African range states. In all cases penalties refer to the hunting and / or exporting of individuals or derivatives without the necessary permits. The USD equivalent of monetary penalties is given in brackets for comparative purposes, and has been calculated using the average conversion rates as on 1 June 2013. Currency abbreviations are according to CoinMill.com Currency Converter (available online at www.coinmill.com). Acronyms are: NEMBA, National Environmental Management: Biodiversity Act, Act no. 10 of 2004; ToPS, Threatened or Protected Species, issued in terms of the provisions of NEMBA.

Country	Legislation	Category	Penalties
South Africa	Listed ToPS Species	Vulnerable	A fine not exceeding ZAR 5 million [USD 501 000] or imprisonment for a period not exceeding 5 years.
Namibia	Nature Conservation Ordinance 4 of 1975	Protected	No trade permitted. A fine of NAD 300 [USD 30] for a first-time offence. In the case of a second offence, a prison term may be imposed.
Botswana	Wildlife Conservation and National Parks Act, 1992	Protected	A BWP 10 000 [USD 1160] fine and imprisonment for seven years
Zimbabwe	Parks and Wild Life Act, 1975 (with 2012 Statutory Instruments)	Specially Protected	Imprisonment for not less than nine years (first offence) or 11 years (second offence), and/or a fine equal to four times the economic value of the poached animal [approximately USD 28 000][1]
Mozambique	Forest and Wildlife Act, 1999	Wild Animal (Rare?[2])	A fine of MZN 1000–20 000 [USD 30–670]. If it is deemed a rare species, or one threatened with extinction, the fine may be up to MZN 200 000 [USD 6700]. This law does not apply to subsistence consumption.
Swaziland	Game (Amendment) Act, 1991	Royal Game	A fine not less than SZL 4000 [USD 400] but not exceeding SZL 30 000 [USD 3030], or in the case of default of payment of the fine imprisonment for not less than one year but not exceeding five years. In all cases the fine shall not be less than the replacement value of the animal.

[1]Challender & Hywood 2012.

[2]It is unclear whether Temminck's ground pangolin is considered a rare species and/or a species threatened with extinction in Mozambique. If it is not, then no legislation applies to this species in Mozambique.

of each southern African range state (Table 1). Most range states provide adequate legislative protection for this species; however, in some instances (notably Namibia and to a degree Botswana) the imposed penalties are lower than the potential economic gain of illicitly dealing in pangolins, and are therefore unlikely to be a deterrent. Furthermore, although the legislation exists, enforcement is often lacking. For example, in Mozambique the legislation does not apply to subsistence use but only to commercial exploitation. Likewise in South Africa the legislation is selectively applied and there are no legal ramifications for vendors caught selling pangolins or pangolin products in *muthi* markets. Furthermore, one range province in South Africa (Mpumalanga) does not enforce the national legislation (National Environmental Management: Biodiversity Act, Act no. 10 of 2004 and the Threatened or Protected Species regulations issued in terms of this act). Mpumalanga does, however, afford protection to pangolins under the Mpumalanga Nature Conservation Act 10 of 1998 but the imposed penalties are likely to be lower than those imposed under NEMBA and are dependent on the offence. Despite all the legislation protecting pangolins, both local and international trade in this species continues, and are increasing.

Gin traps

A third threat faced by pangolins, and one that predominantly occurs in areas where commercial farming with small livestock is prevalent, is their capture in gin traps. Gin traps consist of two spring-loaded metal jaws that snap together when a central pressure plate is depressed by the animal standing on it, effectively trapping any animal that steps in it. A number of gin trap designs exist, including traps with serrated jaw edges; jaws that fit tightly together once triggered; and traps that leave a small space in between the two smooth-edged jaws when closed, purportedly to prevent injury to the trapped animal (as required by the National Environmental Management: Biodiversity Act: Norms and standards for the management of damage-causing animals in South Africa [NEMBA]). For the purposes of this review, the term 'gin trap' is used in reference to all three these varieties as well as 'neck-traps' (larger gin traps that are baited and are designed to capture the predator around the neck). Gin traps are widely used on most live-stock farms in an attempt to control damage-causing predators (D.W.P., pers. obs.) despite their use requiring a permit (NEMBA) which is rarely acquired. Pangolins are often caught in gin traps that are indiscriminately set for damage-causing predators, especially when set under-neath or near fences. These traps are infrequently checked and pangolins that are caught in gin traps often die from exposure and starvation, although if found soon enough after capture they can often be released unharmed. The continued use of gin traps is spurred on by the heavy losses experi-enced by farmers as a result of damage-causing predators (Avenant & du Plessis 2008; van Niekerk 2009) and the resultant bounties paid by farmers for every damage-causing predator caught. The extent of the threat posed by gin traps needs to be determined more accurately, but based on available data appears to be far less severe than electrocutions at present.

Habitat loss

Coulson (1989) found pangolins to be absent from areas used for crop agriculture and areas of dense human habitation. Habitat loss has probably had a pronounced effect on the current distribution of pangolins, but as quantitative data on this species' past and present distribution are largely lacking, it is difficult to estimate the magnitude of the effect of land transformation (see also Friedmann & Daly 2004). Land suitable for crop agriculture and human habitation is particularly prone to transformation and reductions in pangolin densities and distribution are believed to be most pronounced in these areas.

Road mortalities

Five pangolins were found killed by vehicles on the N14 between KO and Upington between 1 September 2009 and 31 August 2012, while a further two mortalities were recorded on the N14 east of KO during this period. In the five years prior to this study, at least four pangolins were killed along a 15 km portion of this road, as evidenced by study skins retained by KO. A report was also received of a pangolin being killed on the railway tracks south of KO while crossing the Sishen-Saldanha railway line. Coulson (1989) also recorded road mortalities of pangolins in Zimbabwe. The *ad hoc* nature of road monitoring, coupled with some road mortalities being removed by un-known persons (D.W.P., unpubl. data), suggests that the magnitude of this threat may be higher than reported here.

Poisoning

Two adult and a juvenile pangolin at the Bloemfontein Zoo died after being treated with a dichlorodiphenyltrichloroethane (DDT) solution to treat a tick infestation (van Ee 1966). A second pair of pangolins procured by this zoo also died after being moved to a new enclosure that had been treated with a soluble Lindane solution (containing benzene hexachloride) a month prior to them tak-ing up residence (van Ee 1966). Heath (1992), based on the reports of van Ee (1966, 1978), first proposed that pangolins may be highly suscepti-ble to chemicals, especially those used on crops. Subsequently Friedmann & Daly (2004) proposed that pangolins are susceptible to pesticides, par-ticularly those used to control locusts. No primary source citing the origin of this latter argument could be traced, but it is believed to also originate from the reports of van Ee (1966, 1978), especially considering that benzene hexachloride is used as an agricultural insecticide (Milstein 1966). Agricul-tural pesticides are not believed to pose a signifi-cant threat to pangolins: this species' absence from croplands is most likely due to the higher hu-man population in these areas resulting in greater persecution, the altered habitat no longer harbour-ing suitable prey species, and the land transforma-tion removing suitable refuges. Furthermore, the high pangolin densities encountered in the North-ern Cape province (Pietersen 2013), where spray-ing of insecticides to combat brown locust (*Locus-tana pardalina*) swarms is fairly commonplace, suggests that the threat posed by poisoning is negligible, if a threat at all. The sensitivity of pangolins to chemicals may have been exaggerated and is based on limited observations of *ex situ* circumstances that do not reflect the *in situ* situation.

Pet trade

Although not likely to be a significant threat, one report was received of a farm worker in the Northern Cape province selling a pangolin pup in 2010. This individual almost certainly died, as pangolins are notoriously difficult to keep in captivity and even with specialist care display a high mortality rate (van Ee 1966, 1978; Heath & Vanderlip 1988; Wilson 1994; Heath & Coulson 1997; Yang *et al.* 2007; Challender *et al.* 2011).

POSSIBLE MITIGATION MEASURES

Electrified fences arguably pose the greatest threat to this species at present, although the extent to which pangolins are used in the *muthi* trade still needs to be determined. Furthermore, international trade, especially to the Asian markets, appears to be increasing (Bräutigam *et al*. 1994; Challender 2011; Challender & Hywood 2012), although this is difficult to state with certainty.

Various mitigation measures have been proposed to reduce fence-induced vertebrate mortalities, including 1) raising the height of the offset tripwire, 2) increasing the distance that the offset tripwire is placed from the fence, 3) packing a rock apron along the base of the fence and 4) duty cycling of the electrified fence (the fence being switched on only at night to exclude damage-causing predators from a farm) (Beck 2008). The first two suggestions have been incorporated into the NCNCA 9/2009, while packing a rock apron is employed by some farms (where rocks are prevalent). The use of duty cycling has limited applicability, can only be used on livestock farms, and is only likely to be effective in reducing chelonian mortalities, as many other species that are prone to electrocution, including pangolins, are nocturnal or both diurnal and nocturnal (Beck 2008; Pietersen 2013). Furthermore, many of these mitigation measures are only effective for certain species, or not at all (R. Satekge, pers. comm., 14 October 2011; D.W.P., unpubl. data).

During the course of this study a new 14.2 km-long internal fence was erected on KO for managerial purposes. In an attempt to reduce electrocutions, a three-strand tripwire (rather than the standard single- or double-strand tripwire) was erected along this new fence. The total height of the tripwire array remained the same, but an additional live strand was added to the configuration, which now has a live-earth-live arrangement. In the 30 months since its erection, only a single pangolin has been electrocuted on this fence, a mortality rate of 0.028 individuals.km/yr. This is substantially lower than the rate of 0.09 individuals/km/yr recorded for an established electrified fence at the same site and, considering that newly erected fences are characterized by a disproportionately high mortality rate, may suggest that this configuration is effective in reducing electrocutions, although longer-term monitoring is required to verify this.

A second potential solution to electrocutions is to develop an in-line monitoring unit for electrified fences. Such a unit should be suitable for attachment to an existing fence and continually monitor the volume of current drawn. When an animal is trapped on an electrified fence it creates a short-circuit which results in more current being drawn by the fence. When the monitoring unit registers an increase in the current drawn, it should cut the power to this portion of the fence for a pre-determined period of time. The unit should be able to re-initiate itself after this pre-determined period, and if the fault persists should be able to switch off again. After a pre-defined number of restarts, an error message could be sent via GSM signal to alert the management staff of a persistent fault on the line. Having the current to the affected strand stopped for a period of time should allow the pangolin to uncurl itself and move away from the fence.

Whenever possible, electrified strands should be placed at a minimum height of 300–400 mm above the ground. This should ensure that these wires are high enough for pangolins to pass beneath unharmed and has proved effective in reducing fence-associated electrocutions of chelonians in the Eastern Cape province (A. Fisher, pers. comm., 13 July 2010). Although such a fence would remain effective on farms where large herbivores are present, it may not effectively contain large predators, as these tend to dig underneath fences. This design would also likely allow damage-causing predators to pass underneath unhindered and would thus result in tensions between game farmers and adjoining small livestock farmers. Raising the height of the fence would be a feasible option in areas devoid of large predators and areas where large livestock (*e.g.* cattle, *Bos primigenius*) are exclusively farmed and where small damage-causing predators would thus not be a problem. Ultimately any mitigation measures would need to be cost-effective while still maintaining the integrity and function of the fence in keeping predatory animals either in (conservation areas) or out (livestock farms).

A final possible mitigating measure is to purposefully introduce breaches into a fence. This can be achieved by leaving the smaller holes that are dug underneath a fence open, especially if there is evidence that they are being used by pangolins. Alternatively, a suitable opening such as a concrete pipe, welded mesh tunnel or open metal frame could be inserted into the fence at intervals. Such openings would need to be carefully designed to exclude damage-causing predators while permitting pangolins and other non-target species unrestricted passage.

The losses incurred by livestock farmers due to damage-causing predators are substantial and given the generally low profit margins inherent in livestock farming may be potentially crippling. Many farmers will thus go to great lengths to eradicate damage-causing predators from their farm. The only reasonable measure to counteract the threat of gin traps at present is to educate farmers as to the plight of pangolins. Livestock farmers will continue to use gin traps for the foreseeable future, but if found and released in time pangolins that are caught in these traps can often be released unharmed. Developing more effective ways to control the movements of damage-causing predators and to reduce livestock mortalities would go a long way towards pangolin conservation in that it would reduce the need for other control measures such as the indiscriminate use of gin traps.

Despite habitat loss being viewed as a potential threat to pangolins, one positive indication is that pangolin densities on well-managed livestock (and private game) farms appear to be similar to densities in adjacent conserved areas (Pietersen 2013). With private reserves alone covering 13% of South Africa (Berger 2006), compared to the 5% covered by National Parks (Falkena & van Hoven 2000), private reserves represent a large additional potential habitat for this species. If livestock farms are added to this figure, the area of potentially suitable habitat for pangolins increases dramatically. In addition to providing substantial additional habitat, these areas could also provide effective migratory corridors to sustain gene flow between purportedly isolated populations. Privately owned land may, however, expose pangolins to various anthropogenic threats including persecution for *muthi* and food. The private sector should be actively engaged to determine the current occurrence of pangolins on their property, the potential for this species to occur on their property, and what can be done to protect individuals on their property.

CONCLUSIONS

Based on current data, fence electrocutions pose the greatest threat to pangolins in southern Africa and methods to reduce or even prevent these electrocutions should be sought as a matter of urgency. Further research should be undertaken to assess how widespread these electrocutions are, as well as how electrocution rates vary regionally. The apparent rapid increase in trade, the majority of which is believed to be destined for international markets, is also of great concern. This increased trade may stem from the reduction in Asian pangolin populations, while the demand for pangolins in Asian markets remains high. Africa, as the only other continent with wild pangolins, is thus likely to play an increasingly important role as a source of pangolins and pangolin products for the international markets in addition to the local markets. Trade levels and trade routes should be closely monitored to determine the extent of this trade and the volume of animals in trade. The prevalence of pangolins in the local *muthi* trade should also be quantified. In addition, this species' historical and current distribution should be compared to assess whether there has been a shift or reduction in range. A formal study to ascertain the prevalence of pangolins as road mortalities and as gin trap victims should also be undertaken to assess the magnitude posed by these threats. Landowners should be actively engaged to determine the current occurrence of pangolins on their property, the potential for this species to occur on their property, and what can be done to protect individuals on their property. A coordinated public awareness campaign should be undertaken to raise awareness of the plight of this species and the actions necessary to conserve it.

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