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SHORT COMMUNICATION

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Fence-related mortalities of Temminck's pangolin (*Smutsia temminckii*) in South Africa quantified through a citizen science approach

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Abstract

Fence mortalities threaten Temminck's pangolin (*Smutsia temminckii*) in South Africa. Temminck's pangolins are bipedal, which leads to contact between their unprotected abdomens and electrified wires. We report findings of an online survey of landowners, managers and conservationists to investigate associations between mortalities, fence type and fence perimeter-area ratio, and between mortalities and concern level reported by respondents. Of 14 recorded taxa, pangolins were the second most reported mortalities, with ground-level electric wired fences having a larger negative impact than other fence types.

Résumé

La mortalité due aux clôtures menace le pangolin de Temminck (*Smutsia temminckii*) en Afrique du Sud. Les pangolins de Temminck sont bipèdes, ce qui entraîne des contacts entre leurs abdomen non protégé et les fils électrifiés. Nous présentons les résultats d'une enquête en ligne menée auprès de propriétaires fonciers, de gestionnaires et de défenseurs de l'environnement afin d'étudier les associations entre les mortalités, le type de clôture et le rapport périmètre-surface de la clôture, et entre les mortalités et le niveau d'inquiétude déclaré par les personnes interrogées. Sur les 14 taxons recensés, les pangolins ont été les deuxièmes victimes les plus signalées, les clôtures électriques au sol ayant un impact négatif plus important que les autres types de clôtures.

1 | INTRODUCTION

Fencing used for wildlife management in South Africa, which surrounds protected areas, private land and game reserves, can inadvertently harm wildlife by electrocution (Beck, 2009; Burger & Branch, 1994; Pietersen, 2022). Affected species include Temminck's pangolins (*Smutsia temminckii*), tortoises (family Testudinidae) and snakes (suborder Serpentes) (Beck, 2009; Burger & Branch, 1994; Ferguson & Hanks, 2010; Holt et al., 2021; Pietersen, 2022; Pietersen et al., 2014).

Fence design varies depending on purpose and cost (Jakes et al., 2018). Unelectrified fences may mark residential boundaries, whereas electrified fences can exclude wildlife from livestock, or contain dangerous wildlife, thereby reducing human–wildlife conflict (Ferguson & Hanks, 2010; Jakes et al., 2018; Kesch et al., 2015; Osipova et al., 2018). South Africa has approximately 17 million hectares of private farms and 7.7 million hectares of protected areas, all enclosed by fencing (Pietersen, 2022; Taylor et al., 2016; Taylor & van Rooyen, 2015).

Hunting for traditional medicine practices and the illegal wildlife trade, along with fence mortalities, represent the primary threats to pangolins in South Africa (Baiyewu et al., 2018; Beck, 2009; Challender et al., 2020; Pekor et al., 2019; Pietersen et al., 2014, 2020). Pangolins' bipedal gait can expose their underbellies to low-level electric wires (Pietersen et al., 2014, 2020). In response to this contact, pangolins defensively curl around the wire often resulting in death by electrocution (Pietersen et al., 2014, 2020). Quantitative study of pangolin fences mortalities is limited to date. Beck (2009) conducted a 1-year study at eight sites[1] in South Africa and documented 33 species[2] electrocuted, including four pangolins. Pietersen (2022) reported 27 species killed[3] and 213 mortalities over 5 years at one property in the Kalahari, including 28 pangolin deaths and eight pangolin fence interactions. Previously at the same location, Pietersen et al. (2014) recorded 21 pangolin deaths over 3 years, estimating that 2%–13% (377—1028 individuals) of the South African pangolin population are electrocuted annually (Pietersen et al., 2016). Fences with electrified wire heights of 50–200 mm are particularly problematic for pangolins as they are easily walked into (Bothma & du Toit, 2010; Pietersen, 2022; Pietersen et al., 2014). Wire configuration and perimeter-area-ratio (PAR; the ratio of fence length to an enclosed area, as a fragmentation proxy) (Sobrinho et al., 2003) may influence mortality rates.

Our study employed the first citizen science questionnaire in South Africa to investigate pangolin fence mortality rates compared with other taxa and evaluate associations between mortalities and geographical area, land use, fence type/wire configuration or PAR. We explored associations between mortalities and concern levels expressed by respondents.

2 | METHODS

An online questionnaire assessed fence mortalities in South Africa, using the University of Brighton Jisc portal (www.onlinesurveys.ac.uk/) (Jisc, 2020). Participant selection encompassed self-selection and snowball sampling of landowners, managers, conservationists and land users. South Africa was the focal country but participants from all Temminck's pangolin range states were accepted to compare death rates. Each response from an individual providing data for multiple properties was considered separate. Questionnaire distribution was in English through email (152 emails) and social media (33 social media pages/relevant associations). Participants in South Africa were offered entry into a prize draw for 10 USD $14 (ZAR 250) gift cards (November 2021).

The 33-question survey (Supplementary Materials SI; Data S1) had two parts. Part 1 (21 questions) focused on key fence use and mortality data. Part 2 collected supplementary data, including participant concern level (12 questions). All questions were optional, resulting in a varying number of responses for each question. Question types included: single-answer choice, multi-answer choice and open-ended questions (Supplementary Materials SI; Data S1). Participants were given six taxa choices to report mortalities: pangolins, lizards, snakes, tortoises, birds, antelope and others. Participants could report as far back as memory allowed. Participants were asked to identify a pangolin from four photographs to verify recognition of the species (Supplementary Materials SI; Data S1). A Likert scale (1—10) was used for participants to select their concern level regarding electrocutions. Participants reported land income sources, fence type/wire configuration, fence length, deaths of all taxa and any use of modifications to prevent electrocutions (Supplementary Materials SI; Data S1). The interactive Canvis.app map (www.canvis.app) (McGill, 2020) allowed participants to mark the approximate locations of mortalities. These mortalities were recorded and analysed separately from the questionnaire reports.

Data analysis used Jamovi (The jamovi Project, 2023). Maps were created using ArcMap (Environmental Systems Research Institute [ESRI], 2020). Statistical analyses included only South African responses to avoid geographical bias. Data from other countries are summarised in Table S1. Fence types were grouped by presence/absence of ground-level electric wires, defined as positioned ≤200 mm above the ground (Beck, 2009; Pietersen et al., 2014; Table S2). Chi-squared goodness-of-fit tests assessed associations between: (i) fence type and species mortalities; (ii) fence type and South African province; and (iii) PAR and the number of species killed. PAR was calculated by dividing the total fence perimeter (km) by the land's total area (km^2). Mann–Whitney *U*-tests compared mortalities between fences with and without modifications. Spearman's rank correlation tests evaluated participant concern level compared with taxa mortalities. All analyses were two-tailed with alpha levels of 0.05.

[1]Tswalu Kalahari Reserve, Northern Cape; Pilansberg National Park, North West; Marakele Pty. Ltd, Limpopo; Jubatus Cheetah Reserve, Limpopo; Venetia Limpopo Reserve, Limpopo; Sabi Sand Game Reserve, Mpumalanga; Phinda Resource Reserve, KwaZulu-Natal; and De Aar Farms, Northern Cape.

[2]Temminck's pangolin, South African hedgehog (*Atelerix frontalis*), black-backed jackal (*Canis mesomelas*), red duiker (*Cephalophus natalensis*), spotted hyaena (*Crocuta crocuta*), lesser bushbaby (*Galago moholi*), small Spotted Genet *(Genetta genetta*), Cape porcupine (*Hystrix africaeaustralis*), honey badger (*Mellivora capensis*), klipspringer (*Oreotragus oreotragus*), aardvark (*Orycteropus afer*), gemsbok (*Oryx gazella*), thick-tailed bushbaby (*Otolemur crassicaudatus*), common warthog (*Phacochoerus africanus*), bushpig (*Potamochoerus larvatus*), vervet monkey (*Simia aethiops*), flap-necked chameleon (*Chamaeleo dilepis*), black mamba (*Dendroaspis polylepis*), boomslang (*Dispholidus typus*), Bells hinged tortoise (*Kinixys belliana*), lobatse hinged tortoise (*Kinixys lobatsiana*), southern marsh terrapin (*Pelomedusa subrufa*), spotted bush snake (*Philothamnus semivariegatus*), Kalahari tent tortoise (*Psammobates oculifer*), olive grass snake (*Psammophis mossambicus*), stripe-bellied sand snake (*Psammophis subtaeniatus*), Southern African python (*Python natalensis*), leopard tortoise (*Stigmochelys pardalis*), southern vine snake (*Thelotornis capensis*), rock monitor (*Varanus albigularis*), leopard toad (*Sclerophrys pantherina*), giant bullfrog (*Pyxicephalus adspersus*) and raucous toad (*Sclerophrys capensis*).

[3]Temminck's pangolin, steenbok (*Raphicerus campestris*), springbok (*Antidorcas marsupialis*), common Duiker (*Sylvicapra grimmia*), impala (*Aepyceros melampus melampus*), springhare (*Pedetes capensis*), cape hare (*Lepus capensis*), Southern African hedgehog, striped polecat (*Ictonyx striatus*), gemsbok, aardvark, waterbuck (*Kobus ellipsiprymnus*), bat-eared fox (*Otocyon megalotis*), black-backed jackal, mountain reedbuck (*Redunca fulvorufula*), rock monitor, Kalahari tent tortoise, black spitting cobra (*Naja nigricincta woodi*), Cape cobra (*Naja nivea*), common ground agama (*Agama aculeata aculeata*), fork-marked sand snake (*Psammophis leightoni*), horned adder (*Bitis caudalis*), puff adder (Bitis *arietans arietans*), kori bustard (*Ardeotis kori*), spotted thick-knee (*Burhinus capensis*), helmeted guineafowl (*Numida meleagris*) and northern black korhaan (*Afrotis afraoides*).

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3 | RESULTS AND DISCUSSION

A total of 44 respondents participated, covering 73 properties (Table S3) from six African countries ($N=70$): South Africa (74.3%, $N=52$), Botswana (11.4%, $N=8$), Tanzania (7.14%, $N=5$), Zimbabwe (4.28%, $N=3$), Mozambique (1.42%, $N=1$) and Namibia (1.42%, $N=1$). Within South Africa, the most common province ($N=44$) surveyed was Limpopo (40.74%, $N=22$), followed by North West (12.96%, $N=7$), Northern Cape (9.26% $N=5$), Mpumalanga (7.41% $N=4$), Gauteng (5.56% $N=3$) and KwaZulu-Natal (5.56%, $N=3$). South Africa incurred the most animal mortalities (93.18%, $N=82$), with 6.82% ($N=6$) in Botswana. No mortalities were reported in other countries (Table S1). Within South Africa, Limpopo reported the most mortalities (50%, $N=36$), then Mpumalanga (15.2%, $N=11$), KwaZulu-Natal (6.94%, $N=5$), Northern Cape (6.94%, $N=5$), Western Cape (5.55%, $N=4$) and Gauteng (1.38%, $N=1$). Most respondents in South Africa reported known pangolin presence on their land (82.69%, $N=43$), with subsequent analyses including only these responses. Most responses came from game ranches (77.77%, $N=21$; Table S4). Our results primarily apply to Limpopo due to the high response rate from here.

Electric fences comprised 81.57% ($N=30$) of fences. These primarily included ground-level electric wires (75%, $N=24$; Table S5). Limpopo had a high presence of multiple (including ground-level) electric wires compared with other provinces ($\chi^2=24.0$, df$=6$, $p<0.001$). No other fence types differed in presence between province (non-electrified $\chi^2=8.00$, df$=6$, $p=0.238$; ground-level only $\chi^2=8.67$, df$=6$, $p=0.193$; multiple electric wires excluding ground-level $\chi^2=8.67$, df$=6$, $p=0.193$; and top-level only $\chi^2=5$, df$=6$, $p=0.544$). Land with low PARs experienced the most mortalities ($\chi^2=19.2$, df$=3$, $p<0.001$); low PAR may indicate longer stretches of each single fence.

Most respondents (61.53%, $N=32$) reported animal mortalities; however, 16 participants with fences had never witnessed any mortalities. The questionnaire recorded 89 mortalities in total. Pangolin (19.51%, $N=16$) was the second most reported species, following tortoises (26.82%, $N=22$; Table 1), with deaths primarily recorded on ground-level electric wire fences (64.86%, $N=25$) (Figure 1). Pangolins, lizards, snakes and tortoises experienced significantly more deaths on fences with multiple electric wires including ground level (Pangolin: $\chi^2=17.0$, df$=3$, $p<0.001$; Lizard: $\chi^2=15.0$, df$=3$, $p=0.002$; Snake: $\chi^2=18.0$, df$=3$, $p<0.001$; Tortoise: $\chi^2=22.7$, df$=1$, $p<0.001$). Bird and other species deaths did not differ with fence type (Bird: $\chi^2=3.76$, df$=3$, $p=0.300$; Other: $\chi^2=3.00$, df$=3$, $p=0.392$). Three respondents reported deaths of lizard ($N=2$), snake ($N=2$), tortoise ($N=2$), bird ($N=2$) and antelope ($N=2$) on non-electric fences. One pangolin mortality was reported on a non-electric fence in Botswana.

Mortalities for nine taxa were recorded on the interactive map ($N=76$). These included: pangolin, aardvark (*Orycteropus afer*), antelope, birds, honey badger (*Mellivora capensis*), lizards, Cape porcupine (*Hystrix africaeaustralis*), snakes and tortoises. Deaths were primarily in South Africa (82.5%, $N=63$) and the remainder in Botswana (17.5%, $N=13$; Figure 2). Limpopo comprised over half of all deaths (51%, $N=39$) and 63.6% ($N=7$) of pangolin deaths (Figure 3). Three (27.3%) pangolin deaths were recorded in North West and one (9.1%) in Mpumalanga.

TABLE 1 Frequency of deaths by vertebrate taxon in South Africa based on an electronic questionnaire survey.

Taxon	Frequency
Tortoise	22
Pangolin	16
Antelope	14
Snake	12
Lizard	8
Bird	5
Other	5 (bat-eared fox (*Otocyon megalotis*), Southeast African cheetah (*Acinonyx jubatus jubatus*), common warthog (*Phacochoerus africanus*), South African giraffe (*Giraffa giraffa*) and African wild dog (*Lycaon pictus*))

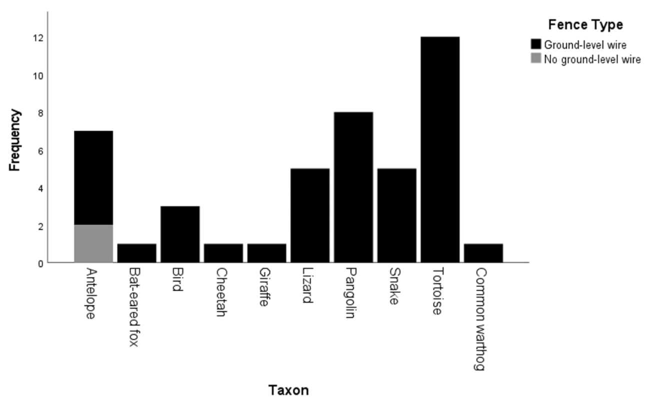

FIGURE 1 Frequency of fence deaths by vertebrate taxon grouped by presence or absence of ground-level electrified wires in South Africa based on an electronic questionnaire survey. One African wild dog (*Lycaon pictus*) record was on an unspecified fence type and was thus excluded.

Fourteen total taxa and 17 pangolin mortalities were recorded in this study, over an unrecorded period. Tortoises, birds, lizards and snakes are species-rich groups (Branch, 1998; Roberts et al., 2005; Skinner & Chimimba, 2005), while pangolins in South Africa are a single, low-density species (Pietersen et al., 2021). Our small sample size, mainly from Limpopo, indicates that pangolin electrocutions primarily occur on fences with multiple electric wires, including ground level.

The presence of fence modifications ($N=12$) did not influence animal mortalities ($U=83.5$, $p=1.000$). Reported fence modifications included modifying tripwires (63.63%, $N=7$) by removing ($N=3$), raising ($N=2$) or lowering ($N=2$); installing physical barriers (18.18%, $N=2$); and using earth wires instead of low electrified wires ($N=1$), low voltage wires ($N=1$) or tunnels under the fence ($N=1$) (18.18%). Most participants (96.15%, $N=25$) were unsatisfied with current methods and were interested in alternative mitigation. Many

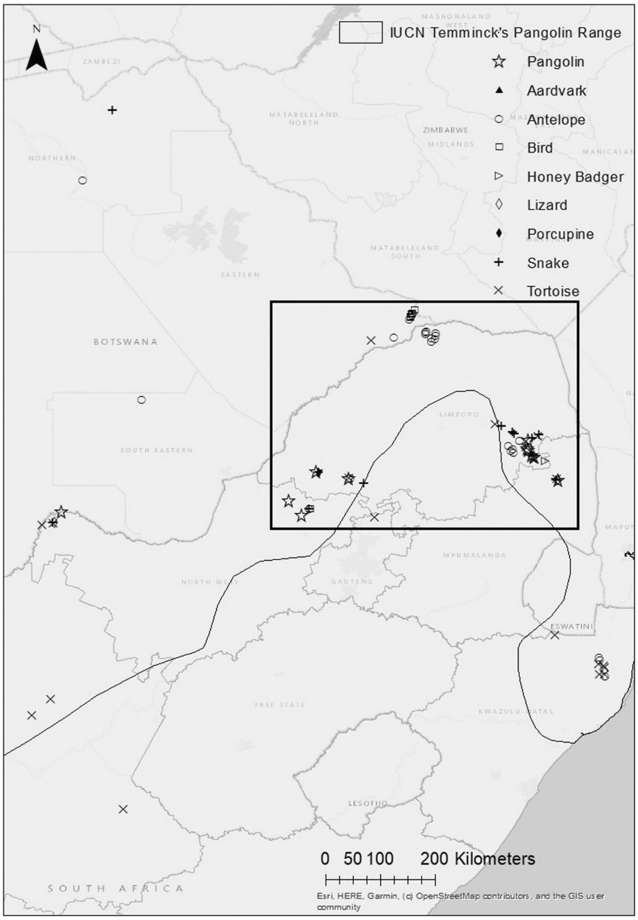

FIGURE 2 Reported animal fence deaths from South Africa and Botswana collected using Canvis.app. The IUCN Temminck's pangolin (*Smutsia temminckii*) range is shown north of the black line (Pietersen et al., 2019). The black rectangle is enlarged in Figure 3.

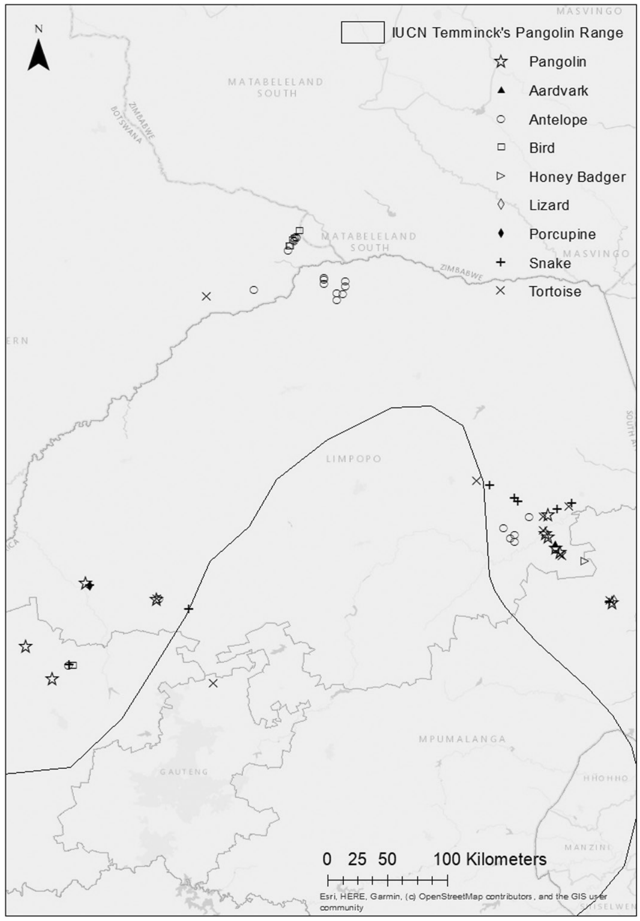

FIGURE 3 Animal fence deaths recorded from northern South Africa and southern Botswana using Canvis.app. The IUCN Temminck's pangolin (*Smutsia temminckii*) range is shown north of the black line (Pietersen et al., 2019).

participants were concerned about animal conservation/welfare (68%, $N=17$). Concern level varied ($N=26$), with 23.1% extremely concerned (score of 10), while 30.77% expressed low concern (scores 1—3; Table S6). Mortalities did not influence concern level (Spearman's rho = 0.379, $p=0.056$).

Potential mitigation methods include raising electrified wires, using physical barriers and implementing timed power-off periods (Beck, 2009; Pietersen et al., 2014). Large-scale testing is needed to reduce mortalities effectively. Currently, one ongoing study is known (Pangolin.Africa, 2021).

Most respondents were from game ranches in Limpopo, which limited our ability to draw conclusions for other regions and land types. COVID-19 travel restrictions limited the questionnaire to those with internet access. Additionally, non-English speakers without automatic browser translation were excluded. Self-selection of respondents means those interested in pangolins or experiencing higher mortality levels may have been more likely to participate. Reporting deaths of protected species is a sensitive topic, so some landowners may have chosen not to participate to avoid association. Participant memory may also introduce bias, as rarely seen species like pangolins may be more memorable than others. Together, this highlights the importance of incorporating stratified sampling into future studies if results are to be considered representative (Fogli & Herkenhoff, 2018).

4 | CONCLUSION

Pangolins were the second most frequently recorded species of 14 taxa killed on fences. The highest death rate was reported on fences with ground-level electric wires versus those without, for all taxa. A negative association between PAR and mortalities suggests that longer fence stretches experience more deaths. Current modifications to reduce deaths appear to be ineffective; thus, further monitoring and research into mitigation are needed.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in ResearchGate at https://doi.org/10.13140/RG.2.2.32909.92642 (Stracquadanio et al., 2021).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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