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Research Article

Landscape habitat occupancy and distribution of the Wild Ground Pangolin (*Smutsia temminckii*) in Zimbabwe's Protected Areas (PAs)

Innocent Mahakata[1]*, Prudence Gonhi[2], Spencer Matindike[2], Yvonne Masumba[2] and Christopher Hungwe[1,2]

[1]Zimbabwe Parks and Wildlife Management Authority, Scientific Services Section-Terrestrial Ecology, Sengwa Wildlife Research Institute, P. Bag. 6002, Gokwe, Zimbabwe

[2]Department of Wildlife Ecology and Conservation, Chinhoyi University of Technology, Bag 7724, Chinhoyi, Zimbabwe

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***Corresponding author:** Innocent Mahakata, Zimbabwe Parks and Wildlife Management Authority, Scientific Services Section-Terrestrial Ecology, Sengwa Wildlife Research Institute, P. Bag. 6002, Gokwe, Zimbabwe, E-mail: innocentmahakata@gmail.com

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Abstract

The *Smutsia temminckii* is the only species of pangolin known to exist in Zimbabwe and is considered vulnerable under the IUCN Red List of threatened species. Distribution of wild *S. temminckii* in protected areas (PAs) and associated environmental variables are not well defined in Zimbabwe. The study sort to relate key environmental variables (Altitude, rainfall, temperature and vegetation type) to habitat occupancy and distribution of *S. temminckii*. Data was collected from forty-eight stations based on S.temminckii sightings historical records spanning ten years (2011-2021) done by field rangers, tourists and scientific services research personnel. A review of available literature was done from online sources and station records. A distribution map based on *S. temminckii* sightings across various PAs in Zimbabwe was developed for this study. Results of this study reveal that *S. temminckii* occupy PAs in South East low-veld areas, Northwestern Zimbabwe, Mid Zambezi Valley and Nyanga NP. No historical data on *S. temminckii* sighting in central PAs located in ecological regions IIa, IIb and III of Zimbabwe. Climatic conditions associated with *S. temminckii* distribution, except for Nyanga NP, are average temperatures above 22^{0}C and rainfall between 400mm to 900mm per annum. Landscapes ideal for *S. temminckii* habitat occupancy have an altitude between 262m-2000m above sea level. Associated vegetation types for habitat occupancy of *S. temminckii* are the Zambezian and mopane woodlands as well as montane forest grasslands mosaic of Nyanga NP. Future studies should focus on establishing distribution of *S. temminckii* outside PA, population status and density to inform conservation of this rare and unique species around Zimbabwe.

Introduction

Pangolins (*Herein refer to in-situ wild pangolin*) are unique medium sized mammals of the order Pholidota [1], mostly solitary species [2]. Pangolins occur at low population densities according to Heath [3]. They are easily recognizable and characterized by their overlapping keratinous scales that cover the majority of their body [4]. Pangolins have a specialized myrmecophagous diet, meaning they feed exclusively on ant and termite species [5].

There are currently eight species of pangolins left in the world with four found in Africa and the other four in Asia [6]. All species of pangolin are currently considered vulnerable to extinction with pangolin populations worldwide rapidly declining due to the excessive demand for pangolin scales from illegal trade [7]. The species of pangolin that exist in Africa are white-bellied tree pangolin (*Phataginus tricuspis*); Black-bellied tree pangolin (*Phataginus tetradactyla*); giant ground pangolin (*S. gigantea*) and *Temminckii* ground pangolin (*S. temminckii*) [8]. *S. temminckii* is the only species of pangolin native to Zimbabwe and it was placed on Zimbabwe's Specially Protected Species list, which affords the species full protection [9].

The conservation of pangolins had become a focal point of interest to conservationists due to their disappearance in some of their suitable habitats [10]. One of the major impediments to conservation of wild pangolins has been related to difficulty

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knowing their distribution and locating them according to Maurice, et al. [11]. In Zimbabwe, there is no data to explain its distribution as well as their favorable conditions for survival [7]. Furthermore, pangolins are predominantly solitary, nocturnal animals that become more active during the night rendering difficult to determine their distribution and abundance can be underestimated. Pangolins are burrowing species and are particularly difficult to locate owing to their burrows which reach a depth of several meters [12]. Pangolins use several burrows within an individual range, occupying each for one to two weeks at a time [13].

According to Darren, et al. (2021) *S. temminckii* is the most widely distributed African pangolin species, very charismatic but poorly known although known to occur across savannah woodlands with moderate-dense scrub, floodplain grasslands, rocky slopes and sand veld as mentioned by Coulson [14]. *S. temminckii* is a terrestrial species that is present in various woodland and savannah habitats, preferring arid and mesic savannah and semi-arid environments at lower altitudes, often with thick undergrowth, where average annual rainfall ranges between 250 and 1,400 mm [15]. According to Richer, et al. [16] distribution of pangolin is linked to the presence of prey species and they are regarded as insectivorous (myrmecophagous) species. The *S. temminckii* is largely water independent [17].

In Zimbabwe, *S. temminckii* are believed to occur in most parts of the country although largely confined to Protected Areas (PAs) [18]. However, little is known of the status of *S. temminckii*, and there is a lack of empirical data on spatial distribution in Zimbabwe's PAs. In Zimbabwe, *S. temminckii* sightings had been rarely reported, however, according to Coulson (1979), they occur widely across different landscapes. Pangolin distribution may be influenced by environmental variables such as climate and altitude [19]. Varying weather conditions and terrain may influence pangolin distribution in Zimbabwe. Zimbabwe have five ecological regions with varying weather variables such as rainfall and temperature [20]. Altitude is between 262 meters in the low lying areas of Gonarezhou to 2, 592 meters in the central-eastern side of the country covering Nyanga NP while maximum temperature range between 18°c in the eastern highlands to as high as 36°C in the Zambezi Valley.

Proper conservation *S. temminckii* in Zimbabwe requires baseline information on current distribution and associated habitat requirements. Ecological knowledge is critical in formulating effective conservation and directing resources towards protection and monitoring hence helps to ensure the survival of the compromised mammal species which are mostly sorted for illegal trade [21]. Zimbabwe have only data on the success of the rehabilitation process, while the distribution and survival of these animals across the landscape is rudimentary yet the information is crucial towards monitoring its distribution for conservation purposes.

To date, no efforts have been placed on identifying potential habitats and distribution of the *S. temminckii* in Zimbabwe's PAs. *S. temminckii* lacks suitable quantitative data from which their distributions can be directly inferred as a consequence of their rarity, secretive behavior, nocturnal and occurring in low population densities. *S. temminckii*, are very difficult to survey, and thus, use of historical sightings data on field encounters to map the distribution can give a general picture of its ranges. This project aims to understand the current *S. temminckii* distribution in various PAs of Zimbabwe using field sightings data hence relating distribution to annual rainfall amount and terrain at a broader scale.

Objective

1. To determine current distribution of *S. temminckii* in Zimbabwe PAs using historical sightings data.
2. To relate distribution of *S. temminckii* in Zimbabwe PAs to habitat features such as rainfall, temperature and terrain at a broader scale.

Methodology

Location of study area

The study covered forty-eight statutory PAs in Zimbabwe, inclusive of eleven National Parks (NP), fourteen recreational parks, two botanical gardens, eight botanical reserves, fourteen safari areas, four sanctuaries and two conservancies (Figure 1). The selected PAs are located in different ecological regions at different altitudes characterized by different amounts of rainfall received per annum in Zimbabwe.

Zimbabwe is a Southern African country located between the Limpopo and Zambezi rivers in the south-central Africa. It lies at an altitude of 262 meters in the low veld of the Gonarezhou and 2, 592m above sea level in the mountainous areas of Inyangani to the eastern border. About thirteen percent of Zimbabwe land (390, 757km^2) is under PAs. The landscape is divided into three geographical regions: the inland plateau, the Highveld and the Escapement. The 1.200 m high inland plateau takes up the majority of the country. The landscape sinks to the west into the Kalahari basin. The plateau falls away in the north and south towards the Lowveld.

Climate is typical of subtropical to tropical and temperatures vary with season. Temperatures depend on the altitude of the region and range from as low as 22°c per annum in the eastern parts of Zimbabwe, in Nyanga and Chimanimani to as high as 29°c in the low laying areas of the Zambezi valley. Rainfall ranges from 260mm in the Southern part of Lowveld around the Tuli area to as high as 1400mm per annum in the eastern Nyanga and Chimanimani areas. Average annual rainfall and temperature vary across the landscape. However, localized temperatures and precipitation averaged over time vary slightly with constant maximum and minimum levels.

Zimbabwe is a characteristic of the savanna ecosystem dominated by the miombo, mopane and mixed woodland. In higher altitude mountain forests and large grasslands are common and in the southern parts mopane woodlands, mixed acacia dominated woodlands, teak forests and Baikiaea dominated woodlands are found. Dry savanna with grass of up to two meters height makes up a major part of Zimbabwe's central landscape.

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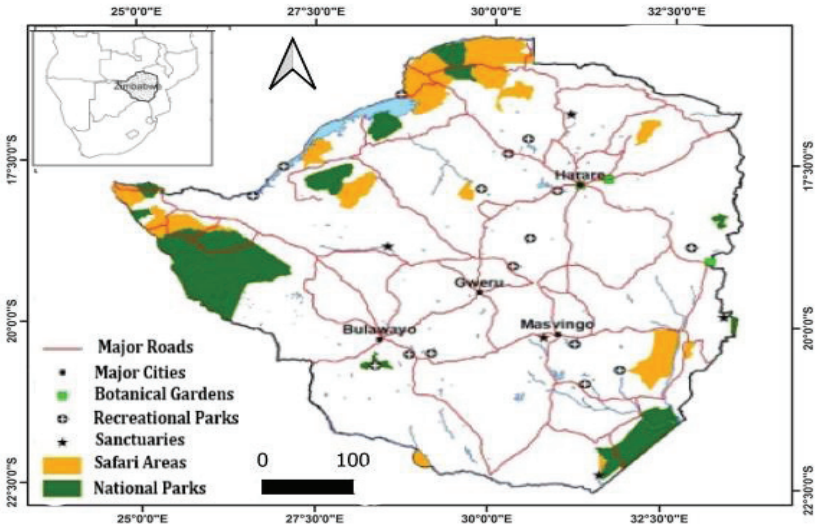

Figure 1: Map showing location of different PAs in Zimbabwe.

Data collection

An extensive historical pangolin sightings data (from 2011 to 2021) and related historical literature was used. Literature was reviewed to collate data from previous studies conducted in Zimbabwe. *S. temminckii* sightings data was collected from forty-eight statutory PAs around Zimbabwe. Data was retrieved from station records supplied by key informants who is the station ecologist (Field rangers, tourists, operators, research team) to the station scientific services personal. A developed data sheet was emailed to all ecologists in different PAs to fill in the relevant information relating to pangolin sightings in the respect park areas. The recordings of *S. temminckii* was based on sightings and indirect signs (such as burrows, tracks, and scats). *S. temminckii* details required was date sighted, name of PA, locality, GPS coordinates and basis of record. Biophysical environment data required was terrain, average annual rainfall and average annual temperatures.

A literature review on the status of *S. temminckii*, annual rainfall variation, major vegetation types and terrain variation for Zimbabwe was done. A review of available published and unpublished literature was done from online sources and the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) reports supplied by the scientific services section. Literature review was done to acquire detailed information on known historical distribution and data of the *S. temminckii* and environmental variables in Zimbabwe. To identify *S. temminckii* distribution in Zimbabwe PAs, and assess related environmental variables associated with their distribution (Rainfall, vegetation types and terrain), data on Zimbabwe's weather conditions, terrain and major vegetation types were searched from google and related to *S. temminckii* sightings across different landscapes.

Data analysis

Based on the GPS coordinates received from different PAs around Zimbabwe on *S. temminckii*, a distribution map was prepared in QGIS 3.16. GPS coordinates were imported into QGIS. Relevant data on Rasta maps showing altitude, mean annual rainfall variation and major vegetation types in different parts of Zimbabwe were imported into QGIS and displayed together with GPS points to show *S. temminckii* distribution maps in Zimbabwe PAs. Rainfall data was used to relate distribution of the *S. temminckii* and was analyzed using the Pearson correlation in Minitab-17. Twenty-six literature data was reviewed to authenticate *Smutsia temminckii* distribution areas concerning the historical data supplied on vegetation types, terrain and annual rainfall to *S. temminckii* distribution in Zimbabwe.

Results

From a total of forty-eight PAs sampled, *S. temminckii* presence data was received from nineteen stations. *S. temminckii* sightings were recorded more in low lying areas of the Zambezi valley and the low veld to the middle areas of the Hwange NP, Zambezi NP and Chirisa SA. Low sightings were recorded in a higher altitude of above 2000m above sea level in the Nyanga NP (Figure 2a,b). Distribution of *S. temminckii* in Zimbabwe were more related to the vegetation of the Zambezian and Mopane woodlands characteristics to other vegetation types. *S. temminckii* distribution in Zimbabwe PAs varied considerably across different ecological regions with different rainfall amounts received annually (Figure 2c). More sightings were recorded in region IV and V with rainfall above 400mm compared to the other areas. However, Pearson correlation of Mean Annual Rainfall (mm) and Sightings recorded showed no correlation between amount (mm) of rainfall received in a particular PA and the number of S.temminckii sightings recorded (Where $r = -0.052$ and $P = 0.724$ at 95% CI).

Discussion

S. temminckii distribution in Zimbabwe PAs

The study found evidence of the wild *S. temminckii* in nineteen PAs across Zimbabwe. No sightings data of *S. temminckii* was received from PAs located in the central part

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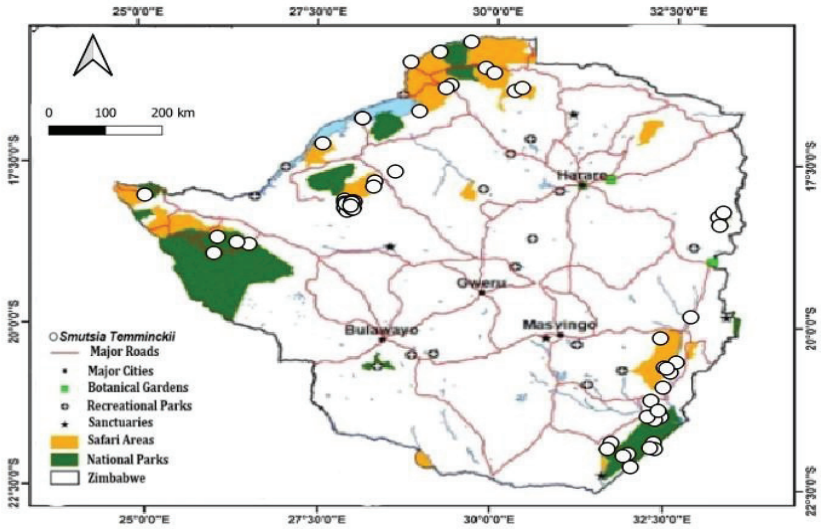

Figure 2a: Distribution of wild *S. temminckii* in PAs.

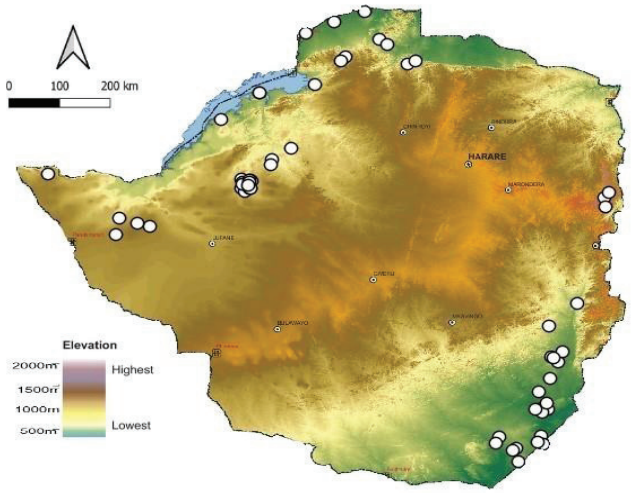

Figure 2b: Altitude map and *S. temminckii* occupancy.

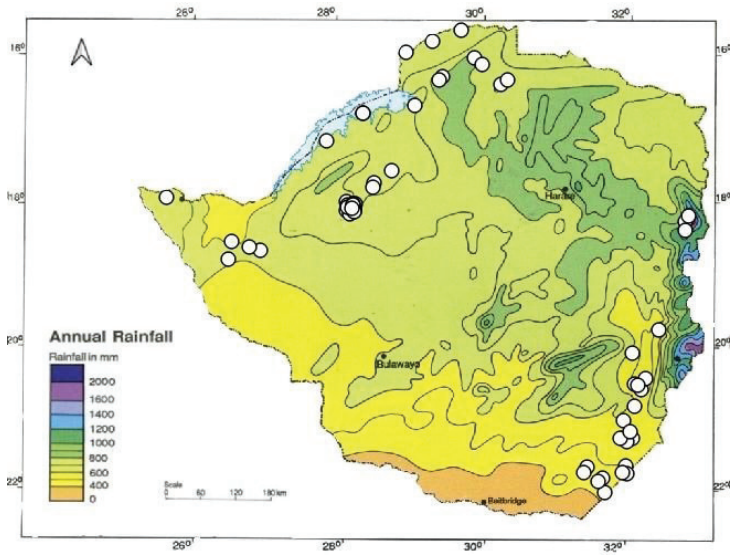

Figure 2c: Average annual rainfall variation across Zimbabwe landscape and *S. temminckii* sites.

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of Zimbabwe. Reports of recorded sightings were received from the Northwest PA of Zimbabwe (Hwange NP, Zambezi National Park, Chirisa Safari Area, Chete), Southeast Lowveld (Gonarezhou and Save Valley conservancy), Zambezi Valley areas (Hurungwe, Charara, Manapools, Sapi, Chewore and Doma) and in the Eastern highlights in Nyanga NP. These findings suggest *S. temminckii* may be largely absent from high-lying savanna woodlands and grasslands that occupy mostly the central part of Zimbabwe and in extreme areas of the southern part of Zimbabwe, where rainfall is below 400m per annum. Hence the results suggest that suitable habitats for wild Smutsia temminckii are areas in the mid to low lying parts of the Zimbabwe.

Highest sightings of the *S. temminckii* were recorded in the marginalised outskirts of central Zimbabwe in Chirisa Safari Area bordering the Chizarira NP in the Northwestern part of Zimbabwe, while Hwange NP, Gonarezhou NP and Save Valley Conservancy had a good number signifying its presence at good densities. On the other hand, low sightings across different PA where data was provided may suggest *S. temminckii* persists in low densities in known range areas compounded by the fact they are mostly solitary and nocturnal meaning they are active during the night.

The presence of *S. temminckii* in PAs in central Zimbabwe, for example, Chivero, Ngezi, Chegutu, Osborne, Kyle and Mushandike remains doubtful, as there was no reports received on wild sightings as well potential sites or heard of the species. Reports received were of *S. temminckii* released after confiscation by law enforcement agents and other pangolin conservation groups such as the Zimbabwe Parks and Wildlife Management Authority and the Tikki-Hywood Trust. However, recordings from such released individuals cannot be used to determine *S. temminckii* distribution because the released animals were confiscated from other areas with their preferred suitable habitats. After release, these *S. temminckii* are never seen and this may explain the type of habitat quality and conditions which may not be suitable for its survival.

Distribution of *S. temminckii* suggests patchy and could be determined by prey availability and other environmental factors [22]. *Smutsia temminckii* are entirely myrmecophagous meaning are selective feeders. According to Swart, et al. [5], *S. temminckii* are selective feeders and this could influence variation in distribution across Zimbabwe PAs. For instance, Smutsia temminckii were recorded in Chirisa Safari area, while the adjacent Chizarira National Park received no reports. Similarly, reports were received from Hwange while the adjacent Matetsi Safari Area had no recent historical data on *S. temminckii* sightings except for those released into the park from confiscated individuals.

Altitude variation and distribution of *S. temminckii* in PA

The findings of the study reveal *S. temminckii* can survive an altitude as low as 263m above sea level in the South East low-veld of Gonarezhou NP to as high as above 1900m in the eastern highlands in Nyanga NP. The results suggest *S. temminckii* can survive in all parts of Zimbabwe PA with similar altitude although other factors may influence its survival. More sightings were recorded in altitudes below 1500m. However, according to Coulson [14] *S. temminckii* can survive in altitude limits ranging up to 1700m above sea level.

PAs located in the central part of Zimbabwe at high altitude above 1500m had no records of *S. temminckii* sightings except for Nyanga NP where three sightings were recorded. Most PAs in the central part of Zimbabwe are located in region IIa, IIb and III. The regions are highly dominated by the Southern miombo woodlands while PAs located in the mid to low lying areas are dominated by the Zambezian and Mopane woodlands. This vegetation type may suggest is the most preferred habitat by *S. temminckii*. According to Richer, et al. [16], feeding sites may be determined by vegetation type. More recordings were done in these areas suggesting suitable habitats for its survival. The PAs dominated by the Zambezian and Mopane woodlands include Hwange NP, Gonarezhou NP, Save Valley Conservancy, Chirisa SA, and the Mid Zambezi PA consisting of Hurungwe, Manapools, Chewore, Sapi, and Doma.

Annual rainfall and temperature variation and *S. temminckii* distribution in PA

The study findings show *S. temminckii* survive in areas with average annual rainfall between 400mm to 1000mm. However, more sightings were recorded in areas with average rainfall between 500mm to 900mm per annum. These areas include the low-veld Gonarezhou and Save Valley Conservancy and the mid Zambezi valley PAs in the low laying areas. However, the study results differ to some extent with the findings by Pietersen, et al. [22] who highlighted that *S. temminckii* can survive in areas where annual rainfall averages can be as low as 250mm to the highest of 1400mm per annum.

Annual rainfall variation may influence habitat quality for the survival of *S. temminckii* across the landscape in Zimbabwe PA. The habitats in which *S. temminckii* were recorded in this study were to some extent similar to those described by Luiselli, et al. (2015), who highlighted that the *S. temminckii* survive in savannah-forest mosaics, dense woodland and riparian forests. However, historical sightings of *S. temminckii* was very poor in areas dominated by Southern miombo woodlands, Zambezian Baikiaea woodlands, Southern africa bushveld and in most parts of eastern Zimbabwe dominated by the Montane forest-grasslands mosaic except in some parts of Nyanga NP. At a localized site, *S. temminckii* occur in floodplain grassland, rocky slopes and sand-veld up to 1,700 m [14,23], but are absent from tropical and coastal forests and Highveld grasslands.

The vegetation types differ across different ecological regions and are influenced by rainfall amount and temperature, and this also influences *S. temminckii* distribution in Zimbabwe PAs and beyond. According to Pietersen, et al. [24] *S. temminckii* distribution in its range is influenced by vegetation type which in most case is a result of the amount of rainfall and temperature of an area. Vegetation type and rainfall are believed to largely determine the presence and abundance of ant and termite prey species and the availability of dens or above-ground debris in which *S. temminckii* shelter.

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The study find out *S temminckii* historical records was higher from areas with average temperatures above 25°c. These are the characteristics of areas that lie in the middle to low lying areas such as the Zambezi Valley, South Eastern low veld and the North West part of Zimbabwe. Even though these areas remain to be favorable sides, *S. temminckii* were also recorded in the eastern highlights Nyanga national Park with average localized annual temperatures around 18°c. Contrary, in the central part of Zimbabwe, in regions IIa, IIb and III, temperatures are moderate around 22°c and this could have an impact on *S. temminckii* distribution in Zimbabwe. The results may explain the suitable habitat and distribution of *S. temminckii* is influenced by temperatures [25-31].

The study acknowledges some limitations on the approach used in this study to gather data on *S. temminckii* distribution in Zimbabwe as well to determine related environmental variables. The data used in the research should be considered preliminary and relatively opportunistic. *S. temminckii* are nocturnal animals and may affect sightings. A further ground survey could have been done to complement historical sightings provided from different PAs across Zimbabwe. The number of *S.temminckii* observed by witnesses cannot be used to estimate density or derive population status but represent occupancy and distribution data. Data used span ten years and *S.temminckii* can shuttle between two or more PAs and can be observed by multiple witnesses, or in the same area, multiple witnesses may observe it. Pangolin species are nocturnal and could influence sightings hence could not totally rule out possibility of *S. temminckii* presence in PAs in the central part of Zimbabwe. Historical data that exist in PAs around the central part of Zimbabwe is based on released *S. temminckii* from confiscation. No post-sightings records after release were provided which could have suggested habitat suitability for *S. temminckii* in the central parts of Zimbabwe. In Zimbabwe, *S. temminckii* is not restricted to pockets of PAs only based on historical data provided. Data could have been collected from other areas outside PA. For example, reports of *S. temminckii* were received from adjacent communities around PAs for example, in Saurombe village in Chimanimani district, Dazi and Nyarumvurwe community in Nyanga District. However, such data is difficult to verify and authenticate its validity without records.

Summary

The study showed *S. temminckii* distribution in Zimbabwe PAs is mainly affected by altitude. *S. temminckii* occupy the marginal areas of Zimbabwe, in PAs found in the South East low-veld (Gonarezhou and Save Valley conservancy), Northwestern side of Zimbabwe (Hwange NP, Zambezi NP, Chirisa, Chete and Charara), Mid Zambezi Valley (Hurungwe, Manapools, Sapi, Chewore and Doma). However, only three reports on historical data were received from Nyanga NP in the eastern parts of Zimbabwe. These areas, except for Nyanga NP are hot areas with an average temperature above 25°celcious and rainfall ranging between 400mm to 900mm per annum. Associated vegetation types at a broader scale are the Zambezian and mopane woodlands that occupy the mid to low laying areas of Zimbabwe, Zambezian Bieakiea woodlands around Hwange and the Eastern Zimbabwe montane forest grasslands mosaic that occupy part of Nyanga NP.

Conservation implications

Effective strategies for the conservation of *S. temminckii* in Zimbabwe PA are affected by limited data on the distribution and abundance of the species. According to Luiselli, et al. (2015) data on pangolin numbers and ranges are limited and this affects efforts to conserve them. However, results warn against the general belief as reported in much literature that *S. temminckii* is widely distributed in Zimbabwe. The study provides first-time information on the *S. temminckii* range areas across Zimbabwe PAs to help inform the development of a National *S. temminckii* conservation program in Zimbabwe. From a conservation perspective, it is encouraging to report that *S. temminckii* populations in Zimbabwe are still found some large PAs. The study suggests that PA managers need to keep a record of *S. temminckii* sightings and use a standard method for data collection based on scientific requirements and recommendations.

Recommendations and future researches

The results of this study present national baseline information for *S. temminckii* distribution and occupancy and serve as an important document for developing and executing conservation action and management plans for the long-term conservation of *S. temminckii* in Zimbabwe. A standard National Pangolin Conservation policy document and a uniform data collection system need to be used in recording sightings in PA and communal areas and for conservation of wild *S. temminckii* in Zimbabwe. Future studies should focus on establishing distribution of *S. temminckii* outside PA, its population status and density, therefore establish ways to conserve its habitats. Habitat preference at a localized site needs to be established as well as identify all possible threats to their survival in Zimbabwe and beyond.

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(Appendix 1)

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