Survival and distribution of Temminck's pangolin (*Smutsia temminckii*) retrieved from the illegal wildlife trade in South Africa

by

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DECLARATION

I, Francois Cornelius Meyer, declare that the dissertation for the degree of Master of Science in Zoology in School of Mathematical and Natural Sciences at the University of Venda, hereby submitted by me, has not been previously submitted for a degree at this university or any other university, that it is my own work in design and execution and that all reference material contained therein has been duly acknowledged.

Signature: ………………………………………

Date: 19/03/2020

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ABSTRACT

Pangolins are medium-sized mammals, characterised by keratinous scales covering their entire body. There are currently eight species of pangolins left in the world with four occurring in Africa and four in Asia. All species of pangolin are currently considered vulnerable to extinction, with their numbers rapidly declining due to the excessive demand for pangolin scales from the illegal trade. This trade is often highly organised and lucrative, making it extremely problematic to counteract. These factors contribute to pangolins now being regarded as the most illegally trafficked mammals on Earth. Within the trade, pangolins are often kept in dire conditions and in cases where they have been recovered, they rarely survive the ordeal. For those that do survive, many assumptions are made when releasing them back into the wild, with only a few cases where actual monitoring has taken place post-release. This study aims to investigate: the demographics of Temmick's pangolin which has been confiscated from the illicit trade in South Africa, the condition of the animals retrieved, survival between release strategies, and their distribution following release subsequent to veterinary treatment. Study animals were fitted with appropriate tracking equipment and monitored post-release to monitor movement and survival. Living pangolins confiscated in South Africa increased from 8 in 2016 to, 40 in 2018, but declined to 25 in 2019, with confiscations peaking during the cold and dryer seasons of winter and spring. Of the pangolins that were successfully confiscated, 63.24% were adult, 14.71% were sub-adult and 22.06% were juveniles. 68% of these pangolins were found in a compromised state. The soft-release approach has become the preferred method of release in South Africa, and current evidence suggest that it has a positive effect on pangolin survival, but more research is still required. Trade related stress was the main root of mortalities and a great cause for concern. Sex of animal played no significant role in susceptibility to poaching, or in survival. Post release monitoring revealed that released pangolins can travel vast distances, and this needs to be taken into consideration when selecting release sites and tracking equipment. Facilitated release procedures have proven to be effective in improving survival probability, but improvements can still be made in all aspects of recovery, treatment and release protocols.

Keywords: Order Pholidota, *Smutsia temminckii*, wildlife trade, reintroduction, soft-release, monitoring, endangered

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1.1 Wildlife Trade

The legal trade in wildlife products is an industry that has increased exponentially within recent years internationally (Douglas & Alie, 2014; Symes *et al.*, 2018) and is now regarded an international multi-billion-dollar industry (Engler & Parry-Jones, 2007). This is primarily due to the high demand in products such as pets, trophies, clothing items, food, and traditional medicine, and is considered to still be growing annually at a rapid rate (Rosen & Smith, 2010). Although the trade in certain wildlife products may be legal and somewhat regulated, the extent of the illicit trade may far outweigh the legal trade and this trade has been recognised as the principal cause of global biodiversity loss (Blundell & Mascia, 2005). However, this illegal wildlife trade is notoriously difficult to monitor and the extent of this trade is often unrecorded or incorrectly recorded (Blundell & Mascia, 2005).

This illegal wildlife trade (IWT) has proven to be well organised, lucrative and difficult to counteract and forms a large component of the global organised crime network (Haas & Ferreira, 2015) that is extremely well structured, notorious to infiltrate and not limited to any single continent or region but rather a global phenomenon (Heinrich *et al.*, 2019; Phelps *et al.*, 2016; Symes *et al.*, 2018). With the increasingly high value placed on these wildlife products, the involvement of other criminal activities alongside the trade in fauna and flora have now also been well documented (Barron, 2015; Symes *et al.*, 2018; Warchol, 2004). For example, the illegal trade in elephant ivory and rhino horn is often used to financially fuel conflict around Africa, by funding international terrorist groups and criminal syndicates (Barron, 2015). As such, this IWT does not only affect the survival of the species in question and the ecosystem from where they were sourced, but also the communities who live adjacent to these systems, and the countries from where they originate (Merem *et al.*, 2018; UK Government, 2014).

Vulnerable and or endangered species are particularly at risk from the growing IWT, with many high-value species already being threatened with extinction (Giangaspero *et al.*, 2014; Merem *et al.*, 2018). For example, the Javan slow loris (*Nycticebus javanicus*), a critically endangered primate (IUCN, 2019), is threatened primarily due to its demand in the illegal pet trade (Campera *et al.*, 2020), lions (*Panthera leo*), are targeted as an alternative for tiger (*Panthera tigris)* bones for traditional medicine use (Douglas & Alie, 2014), African elephants (*Loxodonta africana*), are targeted for their ivory used in cultural symbolism and artwork (Merem *et al.*, 2018) and the black rhinoceros (*Diceros bicornis*) horns used in trinkets, trophies and medicines (Biggs *et al.*, 2013). All of these species are listed as species of conservation concern and face a very real threat of extinction (IUCN, 2019), and all these species are primarily in high demand in Asian markets (Challender & MacMillan, 2014). Pangolins, species of the Order Pholidota, are also on this list and they are now recognized as the most illegally trafficked mammal in the world (Challender *et al.*, 2014).

1.2 Pangolins

Pangolins are unique mammals of the order Pholidota and they are easily recognizable and characterized by their overlapping keratinous scales that covers the majority of their body. When threatened, a pangolin will curl up into a defensive ball, where these scales then act as an effective armour (Wang *et al.*, 2016). These mammals have a specialized myrmecophagous diet, meaning that that they feed exclusively on ant and termite species (Swart *et al.*, 1999).

Pangolins originally evolved from a felid-type ancestor in the North American region of the supercontinent Pangaea and these earliest pangolins migrated into Europe and Asia between 120 and 200 million years ago (mya). The first modern pangolins then evolved from a common ancestor around 87 mya, which led to the Asian pangolin species we know today. The forbearers of the African pangolin species however, migrated from Asia into Africa around 47 mya (Du Toit *et al.*, 2014). There are currently eight species of pangolins that remain in the world, with four occurring in Asia and four in Africa (Challender *et al.*, 2014), all of which are now listed as vulnerable to critically endangered (IUCN, 2019). The only species of pangolin that occur in southern Africa is the Temminck's pangolin (*Smutsia temminckii*) (Fig. 1) (Challender *et al.*, 2014).

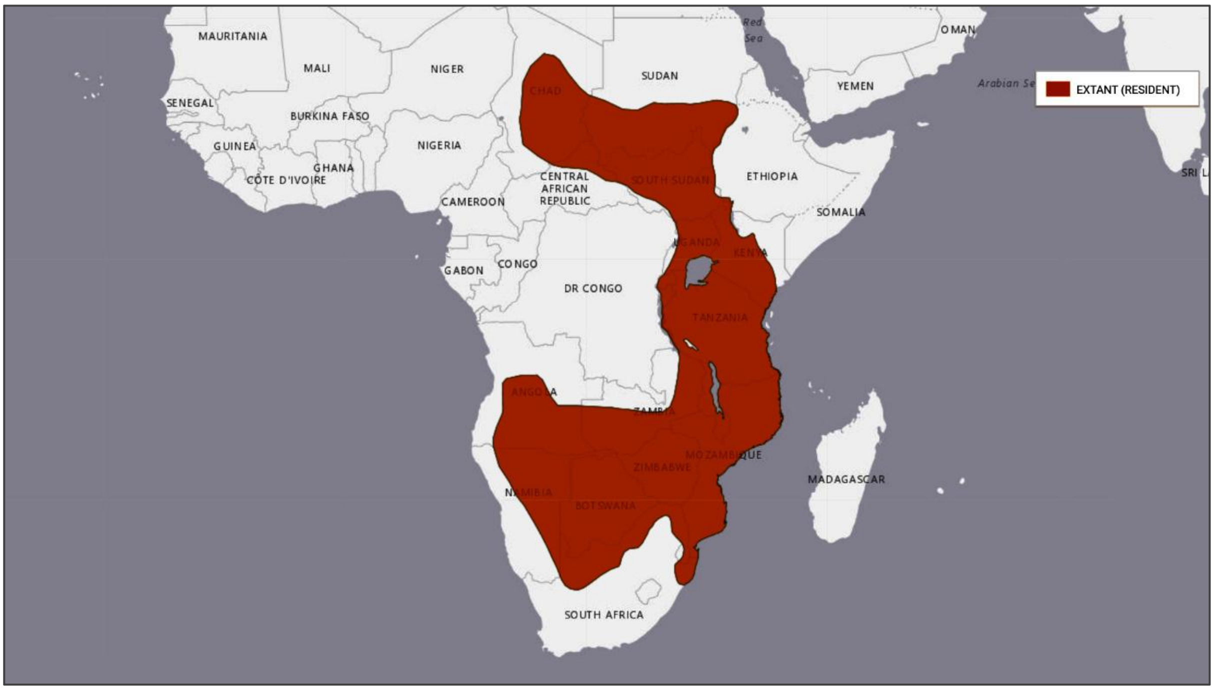

Figure 1. Distribution of the Temminck's ground pangolin (*S. temminckii*) (IUCN, 2019, Pietersen *et al.*, 2020).

1.3 Illegal trade in pangolins

Modern man has been pursuing and hunting pangolins for at least the past 40,000 years (Krigbaum, 2005). This direct persecution of pangolins has even led to the global extinction of the Giant Pangolin (*Manis palaeojavanica*) around that time (Medway, 1977; Corlett, 2007; Piper *et al.*, 2007). Over the years, the hunting of pangolins has continued in both Africa and Asia, where they are captured and traded in high numbers (Corlett, 2007). Pangolins are primarily targeted for their meat in Africa (Boakye *et al.*, 2015) and for traditional medicine in the Asian market (Challender & Hywood, 2012).

The history of the use of pangolins in Africa remains unclear and not well documented (Boakye *et al.*, 2015). Asian pangolins, particularly the critically endangered Chinese pangolin (*Manis pentadactyla*) (IUCN, 2019), of which only small remnant populations remain (Nash *et al.*, 2016), have been used as a source of Traditional Chinese Medicine since the early Northern and Southern dynasties (420 – 589 AD). Medicinal value was primarily related to spiritual ailments and later in the Tong dynasty (618 – 907 AD) for more clinical applications, such as the treatment of malaria (Hu *et al.*, 2012). The demand for pangolin scales has increased in modern times and it has been estimated that upwards of a million pangolins have been harvested from the wild in the past decade alone (Challender *et al.*, 2014).

As the four Asian pangolin species have become even more scarce, the demand for pangolin scales have in turn increased in Africa in order to supply the Asian markets demand. This connection has further been strengthened in the backdrop of the more recent growth in economic ties between Africa and Asia (Challender & Hywood, 2012). Interceptions of pangolin scales from Africa to China have increased remarkably in recent years: 6.4 tons in 2014 (Baker, 2014), 6.3 tons in 2015, 18.9 tons in 2016, 46.8 tons in 2017, 39.7 tons in 2018 and more than 97 tons in 2019 (APWG, unpublished data; Fig. 3 & 4). Unfortunately, these seizures are likely to only represent a fraction of the actual trade as the majority remains undetected (Challender & Hywood, 2012) and crime syndicates involved also operate closely with the trade in other wildlife from Africa in well organised smuggling routes that are regularly adapted (Gomez, 2016). The illegal trade in pangolin scales has now become extremely lucrative as the price for pangolin scales exceeds USD 500 per kg (Zhou *et al.*, 2014), and a whole pangolin's value surpasses USD 6000 per animal (Challender & Hywood, 2012).

South Africa is not exempt from this trade, and the number of live pangolins retrieved from the illegal wildlife trade in this country has increased dramatically in the past few years (NDPP, 2018).

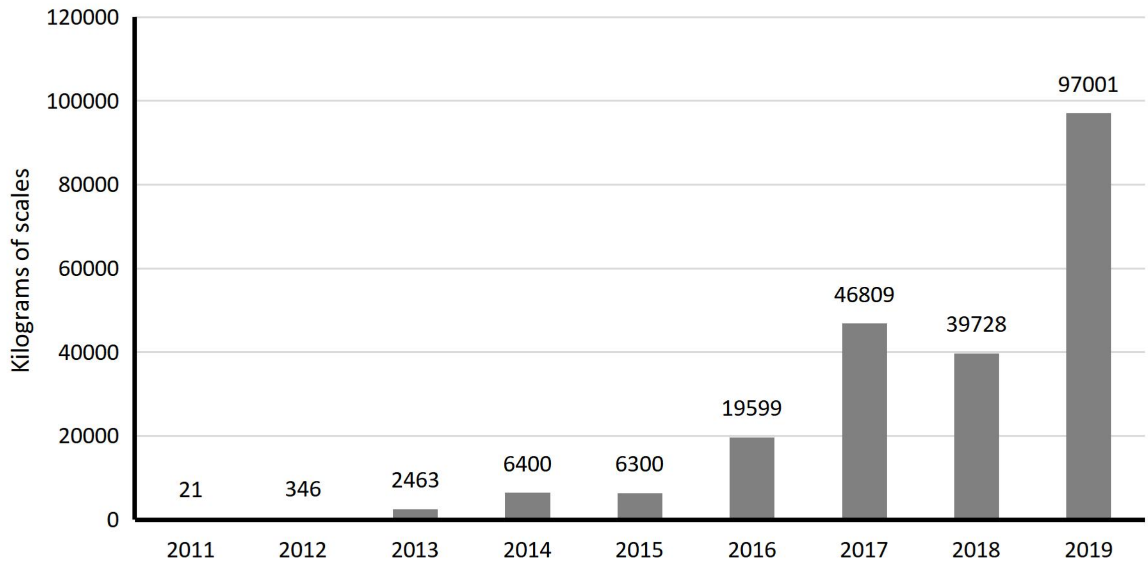

Figure 2: Confiscation of pangolin scales from illegal trade between Africa to Asia, from 2011 to 2019 (APWG, unpublished data).

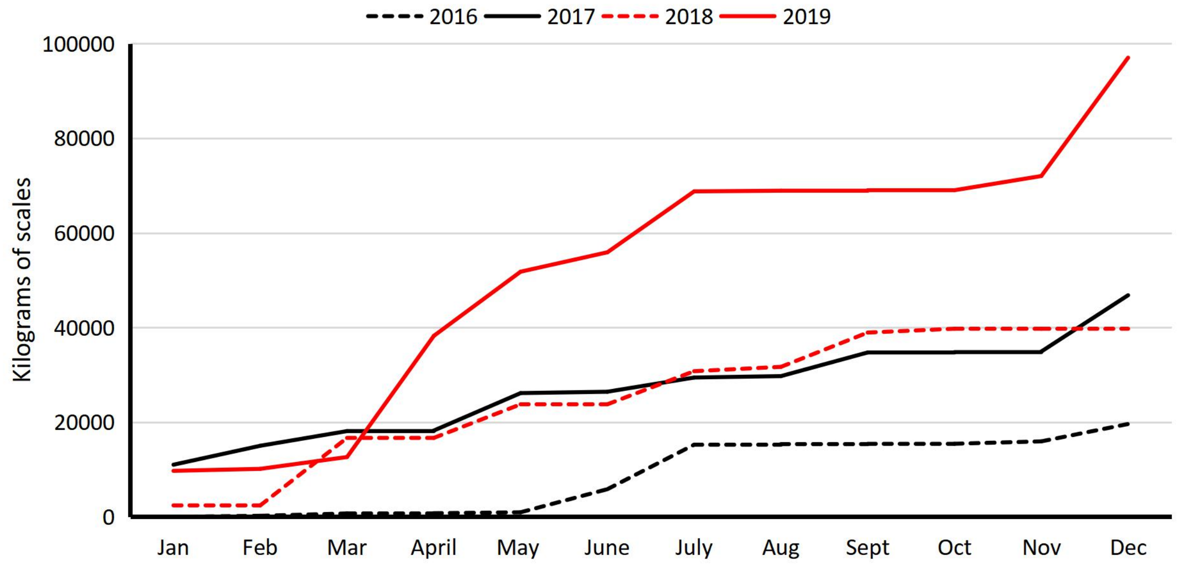

Figure 3: Cumulative monthly records of trade in intercepted African pangolin scales between Africa to Asia, from 2011 to 2019 (APWG, unpublished data).

1.4 Pangolins and the law in South Africa

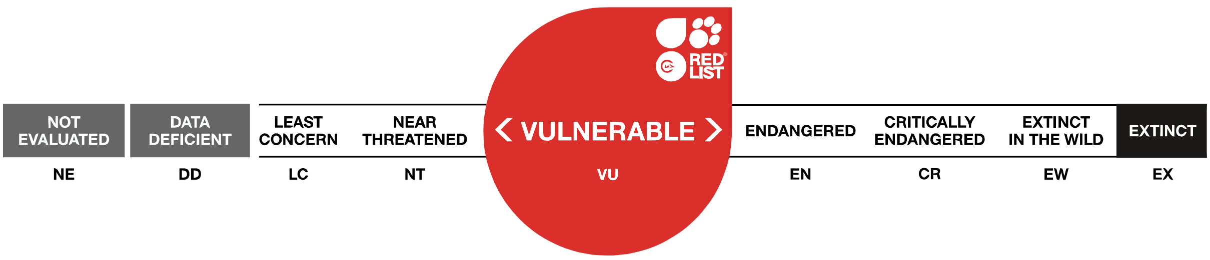

Figure 4: IUCN Red list assessment of *S. temminckii*. Population trend: Descending. Last assed: 1 May 2019 (IUCN, 2019).

Internationally, the Temminck's pangolin is assessed as "vulnerable" by the International Union for Conservation of Nature (IUCN) red list (Figure 4) and up listed to Appendix I on the Convention on International Trade in Endangered Species (CITES) at the CoP17 meeting in 2016 where this classification allows for no commercial trade in any pangolin species globally (Challender & Waterman, 2017). In South Africa, pangolins are listed as a Threatened or Protected Species (ToPS), where a fine not exceeding ZAR 10 million or imprisonment for a period not exceeding ten years, or both such a fine and prison sentence, may be imposed (Challender & Waterman, 2017).

Live pangolins are often brought into South Africa from neighbouring countries such as Zimbabwe and Mozambique as well as locally sourced, often within Limpopo Province (NDPP, 2018). In this country, pangolins are locally protected by the National Environmental Management: Biodiversity Act (NEMBA), Act 10 of 2004 (with 2013 revisions). Provincial legislation differs across all provinces (Table 1) and cases relating to pangolin trade and poaching in South Africa are heard in provincial regional courts by presiding magistrates (NPA, 2018). This regional and national variation often makes sentencing difficult and confusing for regional magistrates, particularly for a species that is notoriously not well known.

Table 1: Provincial legislation related to the Temminck's ground pangolin in South Africa (APWG, 2019).

Province	Status / Listed as:
National	A Vulnerable species in terms of NEMBA
Western Cape	Endangered Wild Animals (Schedule 1) in terms of the Western Cape Nature Conservation Laws Amendment Act, 3 of 2000.
North West	Protected Game (Schedule 2) Section 15 (1) (a) in terms of the Transvaal Nature Conservation Ordinance 12 of 1983.
Mpumalanga	Protected Game (Schedule 2) Section 4 (1) (b) in terms of the Mpumalanga Nature Conservation Act, 10 of 1998.
Northern Cape	Listed as Specially Protected Schedule 1 in terms of the Northern Cape Nature Conservation Act 9 of 2009.
Limpopo	Specially Protected Wild Animals (Schedule 2) in terms of the Limpopo Environmental Management Act, 7 of 2003.
Gauteng	Protected Game (Schedule 2) Section 15 (1) (a) in terms of the Nature Conservation Ordinance, 12 of 1983
Free State	Schedule 1 Protected Game (section 2) in terms of the Nature Conservation Ordinance, 8 of 1969.
KwaZulu Natal	Specially Protected Game (Schedule 3) in terms of the Nature Conservation Ordinance, 15 of 1974.
Eastern Cape	Endangered Wild Animals (Schedule 1) in terms of the Cape Nature and Environmental Conservation Ordinance, 19 of 1974.

Historically, the accused found guilty of trading in pangolins were sentenced to a mere fine ranging from R500 to R10 000 (NPA, 2018). Sentencing has a direct impact and influence on the level of trade, as lesser sentences or fines are not effective deterrents and are not likely to reduce trade numbers (Merem *et al.*, 2018). It has also been evident, that regional courts, magistrates and prosecutors have been unfamiliar with the species and the appropriate sentencing needed for those who were found guilty. The National Prosecuting Authority South Africa (NPA) recognized the increase in poaching and cross-border trafficking of pangolins between 2014 to 2018. This compelled the NPA to consult and include public and private stakeholders such as non-government organisations (NGOs) and species specialists, as to assist with evidence in aggravation of sentences within these cases (NDPP, 2018). This approach has proven to be successful, as improved collaborations and research yielded an increase in arrests and improved sentencing from mere financial fines to jail terms being imposed and carried out. A noteworthy case was during 2018, where the accused was sentenced to eight years imprisonment for attempting to sell a pangolin and again in 2019 where the accused was sentenced to a record eight years imprisonment (NDPP, 2018).

1.5 Recovered pangolins

Both in Africa and in Asia, successful arrest of poachers frequently result in the confiscation of pangolin body parts or living pangolins (Heinrich *et al.*, 2017). Where living animals are recovered, many are sent into veterinary care and rehabilitation centres, before being released back into the wild (Vijayan *et al.*, 2009, Wright & Jimerson, 2020).

Reintroduction of these rescued pangolins have been met with mixed success as very few cases have been recorded where pangolins recovered from the trade have been monitored sufficiently or effectively post-release (APWG, 2019). During a study in 1991, two pangolins were released back into the wild and monitored using radio transmitters. Both these animals were found dead within 10 days of release (Jacobsen *et al.*, 1991). Another study undertaken in 1995 reported a release of a young pangolin, which was recovered from a poacher. This pangolin was monitored using radio-telemetry for 85 days before its transmitter fell off. The release was considered a success, since the pangolin has established a home range within that time (Heath & Coulson, 1997b).

Generally, the monitoring of pangolins has proven to be a challenge as high transmitter drop-off rates have been recorded as well as high levels of transmitter failure particularly with satellite transmitters in past monitoring attempts (APWG, 2019, Willcox et al, 2019). As such, long-term monitoring studies have yet to be undertaken to establish true survival and distribution of these released pangolins (APWG, 2019). No standardized monitoring technique and guidelines have yet been established for pangolins (Willcox *et al.*, 2019) and further studies regarding their monitoring and reintroduction are needed to better establish post-release survival and behaviour (Clark *et al.*, 2008; Perera *et al.*, 2017; Pietersen *et al.*, 2016).

1.6 Problem statement

The expected and inevitable increase in the illegal trade in pangolins will result in increased numbers of confiscated pangolins. Effective rehabilitation and reintroduction of rehabilitated animals will require knowledge on factors directly affecting the survival and successful establishment of home ranges for these endangered mammals. While some studies have made strides into addressing certain aspects (see Wright & Jimerson, 2020), pangolins retrieved from the illegal trade and released in southern Africa have generally been monitored in an *ad-hoc* way. This has resulted in very little behavioural and ecological knowledge, which is critical in formulating effective rehabilitation and release protocols, to ensure the survival of these compromised mammals (APWG, 2019, Heath & Coulson, 1997a, Jacobsen *et al.*, 1991).

As such, there is an urgent need to develop these protocols, not only to aid in the survival of recovered pangolins, but the Order as a whole.

1.7 Research questions

This study has a focus on three general areas regarding the illicit trade in, and recovery of, the Temminck's pangolin. Firstly, we wish to gain a better understanding on the demographics of pangolins within the illegal trade and what factors may play a role in pangolin trafficking. Secondly, we intend to look at the condition of the animals retrieved, what treatment they received and the actual process involved in their release and what role this plays in their subsequent release, distribution and survival back into the wild. Finally, we look at pangolin movements post-release, to gain a clearer understanding of what constitutes a suitable release site for these animals.

Research aims

i) To determine the number of pangolins retrieved by law enforcement authorities in South Africa over the past four years 2016-2019.
ii) To investigate the demographics of the pangolins that have been successfully confiscated during this time.
iii) To present the statistics on the number of pangolins that has died as a result of the trade, the amount of these pangolins that has received treatment/care, and the number of pangolins that has been released during this time.
iv) To present survival data on pangolins that have been monitored post-release, while comparing release protocols.
v) To investigate pangolin movement post-release.
vi) To identify potential obstacles and opportunities for future pangolin release procedures.

1.7.1 Hypothesis

We test several hypothesis relating to the trade, rehabilitation and release of *S. temminckii* and what factors might play a role in the trade numbers of this species. We further investigated what factors might play a role towards increasing their survival once recovered and reintroduced back into the wild. Each hypothesis is based on plausible biological reasons and/or management driven objects. Furthermore, each objective is discussed in detail in the subsequent sections and here we only define the core hypothesis:

i) Poaching of the Temminck's pangolin is increasing annually in South Africa.

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ii) Poaching numbers expected to be at its highest in provinces where pangolins occur naturally.
iii) Number of pangolins retrieved from the illegal trade expected to differ within different seasons.
iv) The susceptibility of pangolins to being poached is affected by age and sex of the animal.
v) Physical condition of pangolins deteriorate within captivity and these animals are vulnerable to the anthropogenic stress consequent of the illegal trade (trade related stress), lowering their odds of survival.
vi) A facilitated release, or "soft-release" approach will improve survival probability of pangolins recovered from the illegal trade.
vii) Trade related stress will play a significant role in mortalities of pangolins post-release.
viii) Pangolins can travel vast distances and reintroduced pangolins will not remain within their selected release site.

1.8 Justification

With the rise in the illegal trade of pangolins in South Africa, the number of arrests and confiscations of poached pangolins increases almost annually (NDPP, 2018). These animals were often either sent into care or they were simply released almost immediately back into the wild. In southern Africa, there is currently an extreme lack of experienced individuals, organisation and facilities that can assess, treat, reintroduce or monitor this species (APWG, 2019). As such, we have no data on the success of either the rehabilitation process, the release protocol or the distribution and survival of these animals.

Further, by gaining a better understanding of the trade, one does not only gain better knowledge to counteract it, but also the opportunity to proactively prepare for the impacts thereof.

As such, it is imperative that further studies are undertaken in addressing pangolin reintroduction and all factors involved in the illegal trade in pangolins (Pietersen *et al.*, 2016). This will aid in building and applying effective protocols which are supported by both experience and scientific knowledge. These protocols include effective confiscations, correct treatments, and least-invasive release and research procedures.

2. Chapter Two: Study area

2.1 Selection

The focal release areas were primarily in private nature reserves in the Limpopo, Mpumalanga and the KwaZulu-Natal Provinces. Release sites selected were regarded as ideal for pangolins in that:

i) they did not have harmful barriers such as electric fence trip-wires or busy roads in a close vicinity,
ii) there was a low likelihood of the animal being poached (low human population density in the region),
iii) the location falls within the natural distribution for the species in suitable habitat,
iv) offer suitable natural foraging species of ants and termites in sufficient numbers, and
v) the selected reserve was equipped with a trained team to monitor the pangolin after its release.

2.2 Approval

Candidate release sites were communicated to the South African Department of Environmental Affairs (DEA), who would send a representative of the Government Scientific Authority to inspect and approve these sites as suitable prior to release. After a site has been approved by the DEA, a member from the African Pangolin Working Group (APWG) was deployed on site to aid in the pangolin release protocol. This included assessment and training of all involved individuals in the necessary tracking and monitoring procedures (refer to sections 3.4-3.6 on release and tracking protocols).

2.3 Surrounding area

In instances where the pangolins could possibly move off the selected release sites, contact was made with relevant surrounding reserves and communities prior to the release. This ensured access to the surrounding properties was possible, as well improved support from communities.

2.4 Selected sites

During the time period of this study, several sites were used for pangolin releases, as approved by the DEA. Active monitoring of these pangolins has been proven to be challenging though, and long-term monitoring has only been successful on three of these sites. These three sites were considered as the primary release sites.

Due to the ongoing risks surrounding this highly trafficked species, these sites location cannot be given nor named. For the purpose of post-release monitoring and movement analysis, focus was placed on one study area, as a case study, where release protocols were first established.

2.4.1 Post-release monitoring site: Case study

The area for the post release ca se study falls between the Limpopo River valley and the Soutpansberg Mountain range in northern Limpopo Province. This area falls within the natural distribution range of *S. temminckii* (Fig. 5) and the presence of pangolins have been regularly reported by the local community. Release points fell between three reserves ranging from 5000 ha in size, to 18 000 ha, to 40 000 ha. These reserves are adjacent to each other, but were separated by fence lines and roads. A total of 11 pangolins were released on 6 sites between 2017 and 2019.

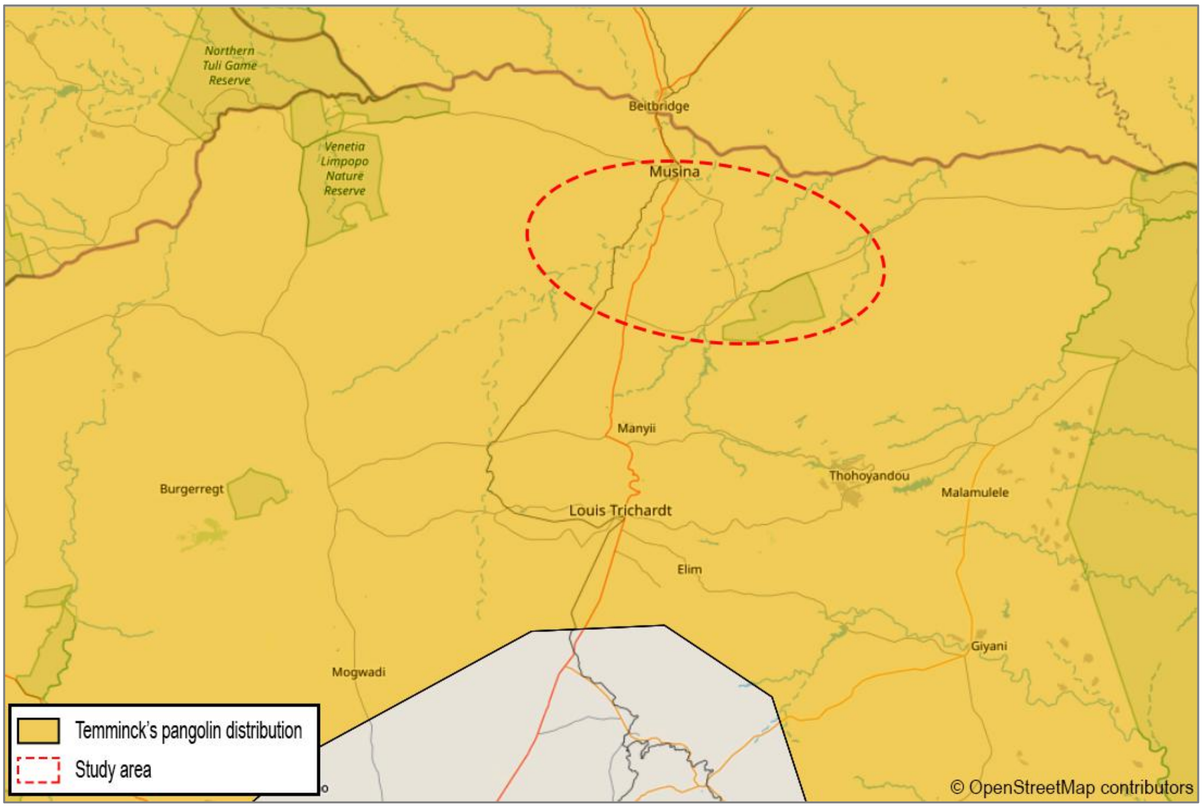

Figure 5: Location of study area and distribution of Temminck's Ground Pangolin (*S. temminckii*) in northern Limpopo Province (IUCN, 2019).

2.4.2 Food availability

Pugnacious ants (*Anoplolepis custodiens*) and cocktail ant (*Crematogaster sp.*) are well-documented food preferences for *S.temminckii* (Pietersen *et al.*, 2016; Swart *et al.*, 1999) and have been recorded in abundance within this mopane vegetation type (Parr, 2008).

2.4.3 Vegetation

This study site falls within the Savanna Biome, Mopane veld, specifically known as the Musina Mopane Bushveld to Limpopo Ridge Bushveld vegetation types (Mucina *et al.*, 2006). The area has a summer rainfall with a mean annual precipitation of 300-400mm. Winters are dry and frost free (Rutherford *et al.*, 2006).

Mucina & Rutherford (2006) describe this habitat vegetation type in detail but in brief the landscape varies from gentle slopes to very irregular plains, hills and rocky-outcrops. Within open woodland and closed shrubveld, *Colophospermum mopane* dominates the majority of the area with clayed bottomlands and *Combretum apiculatum* increases on hill terrain. Open shrubveld areas are mainly dominated by *C. mopane* and *Terminalia prunioides*. Further, open savanna areas mainly contain *C. mopane*, *Termenalia sericea*, *Grewia flava* and *C. apiculatum*. Finally, upon flats and gentle slopes moderately closed tree savanna occurs; *C. mopane* prodigiously dominates here and grows 10-15 m in length with a mostly open upper canopy.

3. Chapter Three: Materials and methods

3.1 Ethics statement

Ethical clearance for this project was submitted to, and approved by, the Research Ethics Committee of the University of Venda (Ref: SMNS/18/ZOO/03/0509).

Recovery operations, animal care and research undertaken, was in collaboration and in accordance with the APWG, the Johannesburg Wildlife Veterinary Hospital (JWVH), DEA and the South African Police Services (SAPS).

All legal documentation, such as the necessary permits for the temporary possession and translocation of *S. temminckii* where applied for from the provincial authority for nature conservation of Limpopo and Gauteng Provinces prior to receiving any pangolins.

3.2 Trade data

All records of national court cases and cases of illegal trade were sourced and supplied from the APWG. The APWG monitors the national database for the illegal trade in *S. temminckii* in South Africa and works closely with the National Prosecuting Authority (NPA) and the DEA in South Africa. Records used for this study ranged from July 2016 to October 2019.

3.3 Study animals

All pangolins involved in this study were confiscated directly from of the illegal wildlife trade in South Africa. Only after these animals received the necessary veterinary assessment and treatment, were they discharged from the hospital and then released back into the wild.

3.3.1 Retrieval and transport

Pangolins recovery from the illegal trade was undertaken in intelligence driven operations by the SAPS and the Government Environmental Management Inspectorate (EMI) often in association with the APWG. These pangolins were then transported to JWVH, with qualified veterinarian and personnel who specializes in the hospitalization, treatment and rehabilitation of the Temminck's pangolin. In cases where a pangolin could not be taken to JWVH directly, a veterinarian approved by JWVH stabilised and treated the animal and who had received the necessary training. Thereafter, the pangolin was sent to JWVH.

Specially built "pangolin crates" were used to cargo and transport the pangolins safely (Fig. 6). Crates were of sufficient size to fit inside a motor vehicle or small aircraft (Fig. 6 A). Both the top (Fig. 6 B) and front of the crates (Fig. 6 C) were fitted with hinged doors to allow easy access to the animal and to facilitate loading of the animal and passive release. These hinged doors locked tightly into place when closed to prevent injuries or escape.

Figure 6: Specially built crates designed to house and transport rescued pangolins. Crate size was small enough to A) make transport effective and to house pangolins temporarily. Crate design allows access to pangolins hinged doors on B) top of crate and C) front of crate.

3.3.2 Veterinary care

Due to the nature of poaching and captivity, recovered pangolins have all undergone varying levels of stress, trauma and/or injuries. This of course means that not all cases are identical and some might call for more extreme measures and unique veterinary care.

During treatment, pangolins were classed accordingly into age groups, sex and general condition. Age classes were classified according to body weight, where animals weighing less than 3.5kg would be classed as juveniles, animals weighing from 3.5 – 6.5kg were classed as sub-adult and animals over 6.5kg were classed as adults. Following veterinary recommendation, no juvenile or sub-adult pangolins under 6.5kg were suitable for release. Any animals under this body weight would remain in specialized care until the desired weight is attained or deemed ready for release.

All age class and condition data used within this study was obtained from these veterinary records.

3.4 Release protocol

The first step in the release protocol was to identify a suitable release zone within the new site. Such a zone would typically include sufficient shelter options, for example aardvark (*Orycteropus afer*) burrows, and adequate prey availability for foraging. Ideally, such a zone would be close to water, but this was not a necessity as *S. temminckii* is mostly water independent (Pietersen *et al.*, 2016).

During this study, two methods of release was practiced. The first was a "hard-release" method, where the animal was released directly into a release site without additional supervision (Kleiman, 1989). The second method, and the preferred method of the APWG and JWVS (APWG, 2019), was a "soft-release" approach.

Soft-release involves habituating the pangolins to their new environment, allowing for acclimatization before their final reintroduction. The normal duration for a soft release is approximately five days, where the pangolin is monitored meticulously each night. Each evening involves a three to five-hour foraging session, after which it is then returned to its crate. During this period the pangolin is weighed daily prior to foraging, and then post foraging, to determine volume of food intake and if the animal has lost body-weight (Wright & Jimerson, 2020). Depending on the pangolin's behaviour and condition, this soft-release approach could take longer than the prescribed five days. Therefore, the handler conducting the release should always be in contact with an experienced veterinarian or field researcher.

Before a pangolin was deemed ready for its final release the following conditions needed to be met during the soft-release procedure. These conditions are prerequisites established by APWG in 2019:

i) Condition: Body weight of the pangolin stabilizes. Any loss of more than 1 kg was considered negative (K. Lourens, pers. com., 2018) and the animal would be returned to veterinary care.
ii) Balance: The Temminck's pangolin walks in a bipedal fashion where the long tail acts as a counter-balance to the front of the body (Pietersen *et al.*, 2016). When the animal is constantly walking on all four or/and the tail is dragging continually, this counter-balance is not operating effectively and it is normally a sign of the animal being exhausted or compromised in some way (personal observation). If this behaviour was observed and it continued for more than 24 hours, the animal was retrieved and returned to veterinary care.
iii) Behaviour: Constant movement in a straight line was considered stressful, or fleeing, behaviour. Soft-release would continue until a more circular movement pattern or "figure of eight" could be observed. This circular pattern of movement is associated with foraging behaviour and considered as normal pangolin movement behaviour (R. Jansen, personal communication, 2018).
iv) Approval: Prior to final release, these conditions were communicated and agreed upon between (a) the field monitor who physically observed all of these conditions, (b) an experienced field researcher and (c) a practicing veterinarian with experience in treating this pangolin species.

3.5 Tracking equipment

Prior to release, pangolins were fitted with a custom designed VHF transmitter (Fig. 7 A; <5% body weight of animal, ® African Wildlife Tracking) onto one of the dorsal posterior scales approximately 10 cm above the base of the tail (Fig. 7). Two small holes (5 mm in diameter wood drill bit) were drilled into this scale and the transmitter was then bolted in place. Pangolins are not required to be sedated for this process and this method is considered effective and non-detrimental to pangolins (Pietersen *et al.*, 2014a). Transmitter life span is approximately 15 months and signal distance strength (line of sight) is >20 km.

As a trial during this study, in addition to the VHF transmitter, some pangolins were fitted with a ®Global Supplies SatTrac tracking unit (Fig. 7 B). These units were placed anteriorly to the VHF system (Fig. 7). The SatTrac units weigh was 112g (including batteries and mounting hardware) with dimensions 55 x 65 x 20mm. These units used the Globalstar Simplex Data Network technology and according to stationary tests, it could log 2500+ GPS locations. To conserve battery life and memory, the units were programmed to log GPS points every two hours after 16:00 in the afternoon, during times when the pangolins were

most likely to be out of their borrows or shelters (APWG, 2019, personal observation).

Figure 7: Pangolins fitted with A) a VHF radio transmitter and B) a SatTrack GPS tracking unit.A total of 41 (20 males and 21 females) pangolins were fitted with the VHF tracking

system for the duration of this study with a total of 19 (11 males and 8 females) pangolins fitted with the SatTrac system.

3.6 Pangolin monitoring protocol

Pangolins were monitored with the primary goal as to assess the condition of each pangolin post-release and to record the survival and distribution following release. In these circumstances, gaining a visual on the pangolin is vital, as this is most effective means to assess its condition and to determine success of the release (K. Lourens, personal communication, 2018, Wright & Jimerson, 2020).

VHF radio tracking made use of a Telonics TR-4 Receiver connected to a Telonics RA-14K rubber-duck "H" Antenna via RW-2 coaxial cable. During these pursuits, tracking continued until a visual of the pangolin, or evidence of its presence, could be obtained. On the ground, without the aid of an elevated position, VHF signal range varied between two to three kilometres and pangolins that had travelled in excess of these distances could only be located via their most recent satellite transmitter location log.

Additionally, GPS data (latitude and longitude coordinates) was recorded as to gain a better understanding of pangolin movements post-release, and if these pangolins would remain within the sites where they have been relocated. GPS readings were recorded using a Garmin® GPS (accurate to within 5 m of the animal).

In the cases where a SatTrac system was also fitted to a pangolin, using the provided tracking software (Wialon by Gurtam), GPS locations were directly uploaded to the Globalstar Simplex Data Network and accessed on-line, it can then be exported directly into a worksheet format.

For the first two weeks following release, each pangolin was located twice a day, once in the morning to determine total movement for that period and to locate the pangolins shelter type and once in the late afternoon or early evening to gain a visual on the animal. Following which, the pangolins were located twice a week for a duration of three months, and then finally once a week for the next nine months. This method of monitoring is the current standard procedure for Temminck's pangolin released in South Africa (Wright & Jimerson, 2020).

With pangolin home ranges estimated to be between 4 km^2 to 7 km^2 (Pietersen *et al.*, 2014a), we chose a 5 km radius from the point of release to be considered as a broad "release zone" (R. Jansen, personal communication, 2018). When a pangolin moved beyond this radius, or beyond VHF tracking range, it was considered to have moved "off-site".

When a pangolin moved beyond monitoring range, and there was no evidence that a mortality occurred, the animal was marked as "Signal: lost" and its last known status logged (Table 2). Hereafter, on a monthly basis, VHF telemetry scanning would continue on lost pangolins, not only in an attempt to locate them, but also to confirm that they had survived and indeed moved off-site.

In cases where the animal's health was compromised or where its condition was observed to deteriorate, it was taken from the field and transported back into veterinary care. In these cases, it was still considered to be under veterinary care and not yet released.

3.7 Data analysis

The focus here is on those factors that may contribute towards the illegal trade in pangolins as well as post release survival and distribution of confiscated pangolins. This study investigates several hypotheses with regards to confiscated pangolins, all of which were based on current available records and questions derived from field experience. Due to incomplete historical records and limited time constraints, data records used in this study ranged from July 2016 to October 2019.

Software used during this study includes: Microsoft Excel 2016, R (version 6.3.2; R Core Development Team, 2019), RStudio (version 1.2.1335) and QGIS (version 3.8). All software, excluding Microsoft Excel, are open-source software and free for public use.

Bar charts was constructed making use of the software program R together with the extension package, *ggplot* (Wickham *et al.*, 2016). In all cases where chi square tests were run, R's native package commands in combination with the *gmodels* (Warnes *et al.*, 2018) extension package (Field *et al.*, 2012) was used. Survival probability was calculated by making use of native packages in R, together with the *survival* (Therneau & Lumley, 2019) and *survminer* (Kassambara *et al.*, 2017) extension packages.

3.7.1 Pangolins retrieved from the trade

To statistically compare variation in the number of pangolins retrieved from the trade, as well as the ratios between male and female pangolins confiscated within each year, chi square analysis was employed.

Next, in investigating the number of pangolins confiscated within and between each province, chi square analysis was run to test whether the difference in the number confiscations between each province was significant or not.

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Annual records were used to calculate the total number of pangolins that has been recovered within each season. December 1st to Feb 28th fell withing Summer, March 1st to May 31st within Autumn, June 1st to August 31st within Winter, and September 1st to November 30th fell within Spring. Again, chi square analysis was used to investigate the number of pangolins retrieved out of the trade between seasons, as well as the ratios between total male and female pangolins within each season.

Further, annual records were used to determine the age distribution of pangolins confiscated, namely "juvenile", "sub-adult" and "adult". Chi square analysis was used to investigate the number of pangolins within each age class, as well as the ratios between total male and female pangolins.

3.7.2 Condition and care of recovered pangolins

Although limited, available records were used to calculate totals of pangolins retrieved in different health conditions classes, ranging from critical, to poor, to average and then good. Good condition was considered to be optimal, where critical to average conditions were considered as compromised. Chi square analysis was run to investigate the number of pangolins between each condition class, as well as directly between optimal and compromised. Finally, chi square analysis was run to investigate the ratios between sexes in each condition class.

In investigating the survival within veterinary care, the total of animals that have received veterinary care was calculated, the total amount that survived to be released, and the total mortalities. Chi square analysis was used to determine if survival had a significant effect on the number of pangolins which received veterinary treatment.

3.7.3 Survival analysis

With regards to pangolin survival post-release, the total of pangolins that survived was calculated together with total mortalities. These totals were further subdivided into release procedure methods, i.e., "hard" and "soft" releases, and also the total amount of male and female pangolins. To test weather release method or sex of pangolin has a significant effect on pangolin survival, the Fishers exact test was run using the *gmodels* extension package for R (Field *et al.*, 2012).

Historical data on survival and mortalities were collected from numerous past records, all under varying circumstances and conditions. Many of these records were incomplete, and inadequate records were discarded from statistical analysis. Furthermore, due to the unpredictability of obtaining our sample animals, not all pangolins could be released at the same time, or could be monitored for the same amount of time or within the same conditions. Therefore, in calculating the effects of release procedure type on survival probability, a semi-parametric Cox proportional-hazard model was used. Such a model is commonly used in cases such as this as it can process restricted data and estimate the relationship between the hazard rate and the related variables, without depending on a baseline hazard function (Abdelaal & Zakria, 2015; Swanepoel *et al.*, 2015).

3.7.4 Mortalities

After classifying observed mortalities into relevant associated categories based on underlying cause of death, namely "unnatural", "natural" or "trade-related", chi-square analysis was used to examine the trend for mortality once a release had taken place and the pangolin had died.

3.7.5 Off-site movement

The total of pangolins which dispersed off the allocated release sites, five-kilometre radius, were calculated and categorized in which time period (month) they have done so. Further, these totals were subdivided into release method type, as well as the totals of male and female pangolins. Chi square test was again employed to investigate if there was an association with duration following release, where the animal had dispersed off the allocated release site. Next, to further investigate if there were any differences between sexes, or the release method types, with off-site movement the Fishers exact test was executed.

3.7.6 Distribution maps

GPS data points were imported in RStudio, and using extension package *adehabitatHR* (Calenge, 2011), Kernal home range estimates were calculated at 50% use and 95% use and the Minimum Convex Polygon (MCP) was then exported into vector format. Relevant vector data was imported into QGIS and displayed together with GPS points and presented as the movement range. It is important to note that these are not home range calculations that require fine-scale habitat use data but rather a presentation of the extent of distribution over time following the release of the pangolin.

4. Chapter Four: Results

4.1 Trade in South Africa

Historical records and ongoing data collection indicate that a total of 101 pangolins have successfully been recovered from the illegal wildlife trade in South Africa from July 2016 to October 2019. Of these, 90 were alive when confiscated, and these animals formed the basis of the study. In subsequent analysis, we excluded all cases where the sex of the animal could not be verified which made up a total of 21 pangolins over this period (2016: 8, 2017: 9, 2018: 3, 2019:1).

4.1.1 Annual totals

Of the 90 living pangolins confiscated, 37 (41.11%) were identified as male, 32 (35.56%) as female and 21 (23.33%) unknown sex. There was no significant difference between sexes between years for confiscated individuals ($\chi^2(2) = 1.841$, $p = 0.398$; Fig. 8B) and we therefore excluded sex in temporal analysis. There was a significant effect of year on number of pangolins retrieved ($\chi^2(3) = 4.578$, $p = 1.892 \times 10^{-5}$; Fig. 8A), where the most pangolins were retrieved during 2018 (44.44%) with a slight decline in 2019 (27.78%).

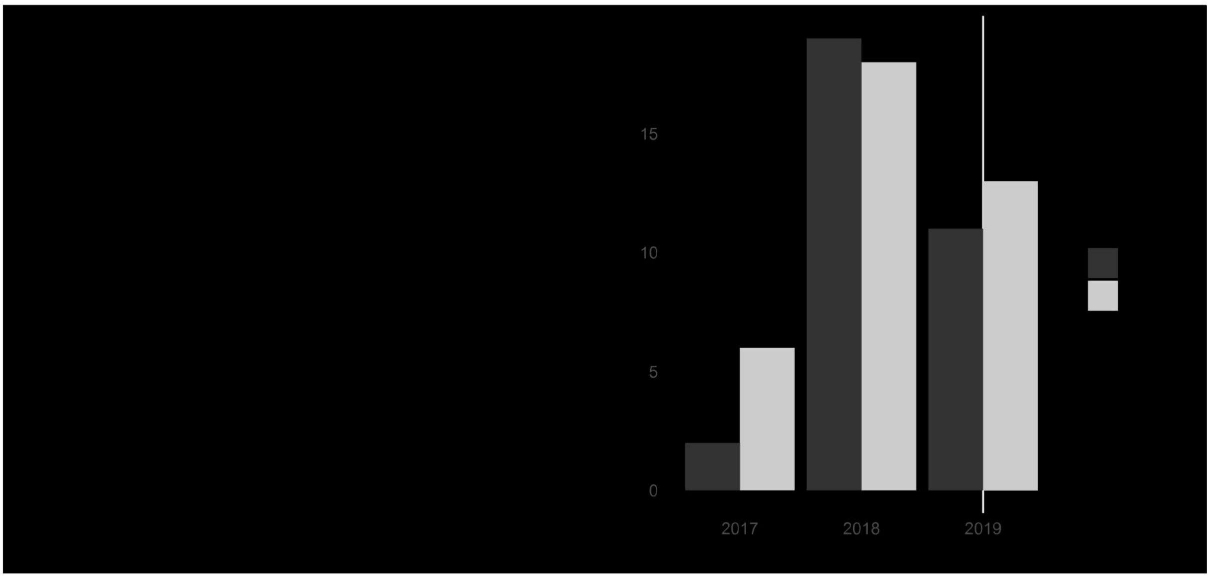

Figure 8: A) Total of living pangolins confiscated from the illegal trade in RSA from 2016 (July) to 2019 (October). B) Annual recorded totals of living female and male pangolins recovered, where all "unknown sex" recording have been excluded.

4.1.2 Provincial variation in confiscations

When comparing the different provinces where successful pangolin confiscations were recorded, it could be seen that these confiscations mainly took place in six of the nine provinces in South Africa. There was a significant difference between provinces with regards to the number of confiscations ($\chi^2(5) = 113.2$, $p < 2.2\text{x}10^{-16}$; Fig. 9), where the large majority of confiscations took place in Limpopo (53.33%) and Gauteng (27.78%) Provinces and no living pangolins were retrieved from the Western Cape and the Free State Province during this time period.

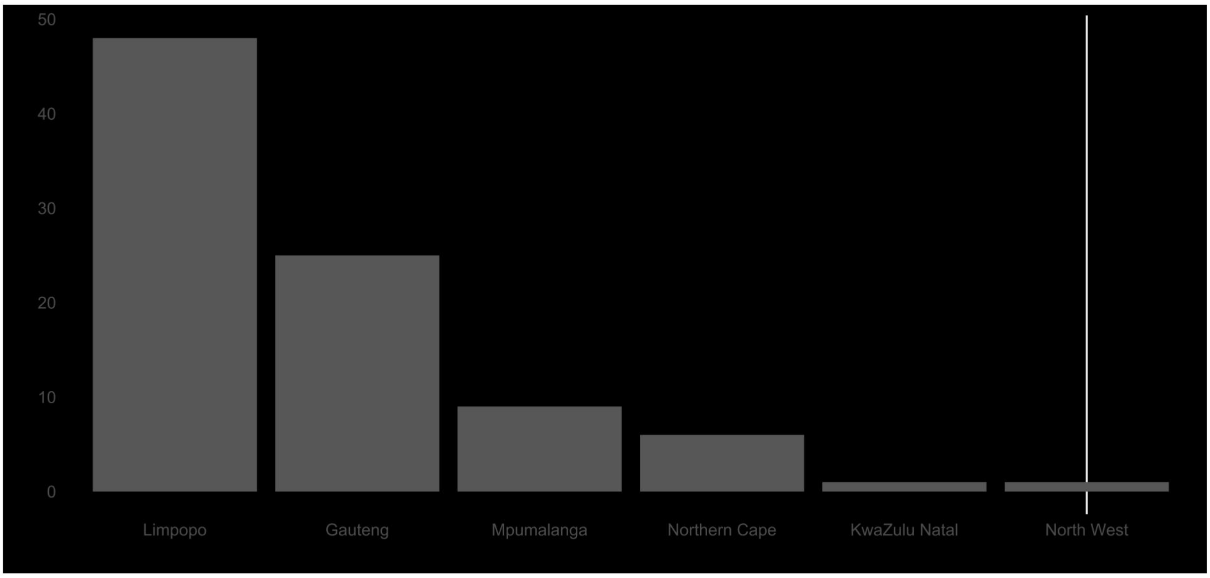

Figure 9: Total living pangolins confiscated from the illegal trade in RSA (July 2016 to October 2019), arranged according to the provinces where recoveries took place.

4.1.3 Seasonal variation in confiscations

There was no effect of season on the sex of pangolins confiscated ($\chi^2(3) = 1.44$, $p = 0.697$; Fig. 10B). When sex was removed as a criterion in the analyses, the variation was significant ($\chi^2(3) = 18.98$, $p = 0.0002763$) in that the large majority (44.44%) confiscations took place in spring (Fig. 10A), followed by winter (22.22%), autumn (17.78%), and then summer (15.56%; Fig. 10A)

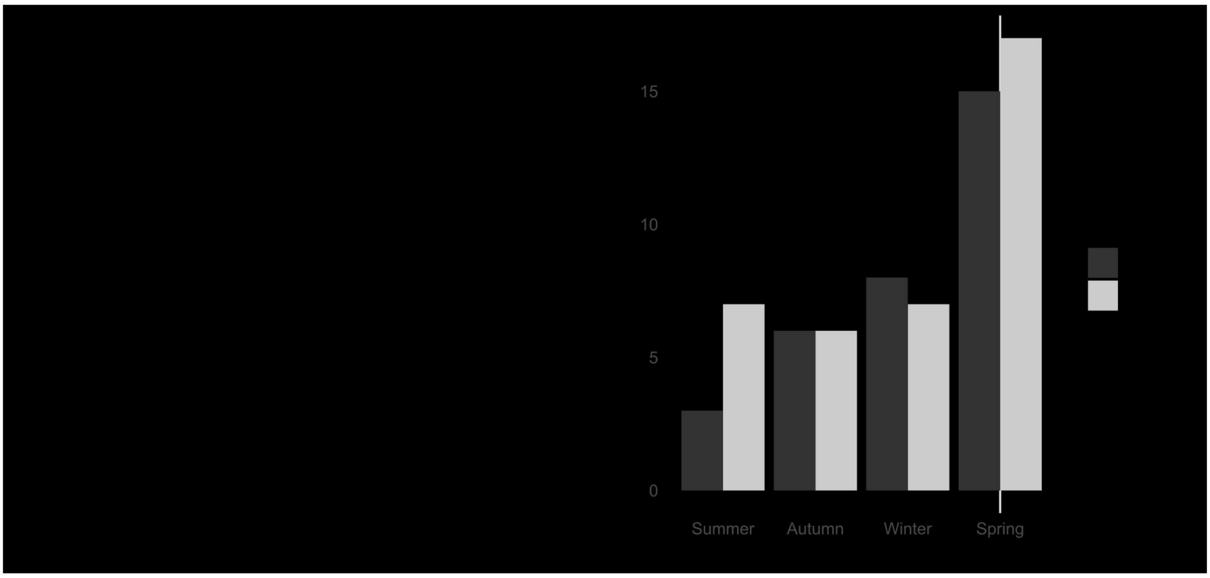

Figure 10: A) Seasonal variation of living pangolins confiscated from the illegal trade in South Africa (July 2016 to October 2019). B) Seasonal variation of living female and male pangolins recovered, excluding all “unknown sex” recordings.

4.1.4 Age distribution within pangolin confiscations

There was no significant variation of sex between age groups of pangolins confiscated ($\chi^2(2) = 2.80$, $p = 0.247$; Fig. 11B). However, when sex was removed from the analyses, there was a significant difference in the age group of pangolins retrieved ($\chi^2(2) = 27.91$, $p = 8.69 \times 10^{-7}$; Fig. 11A) in that the majority of retrieved animals were adults (63.24%), followed by juveniles (22.06%) and then sub-adults (14.71%).

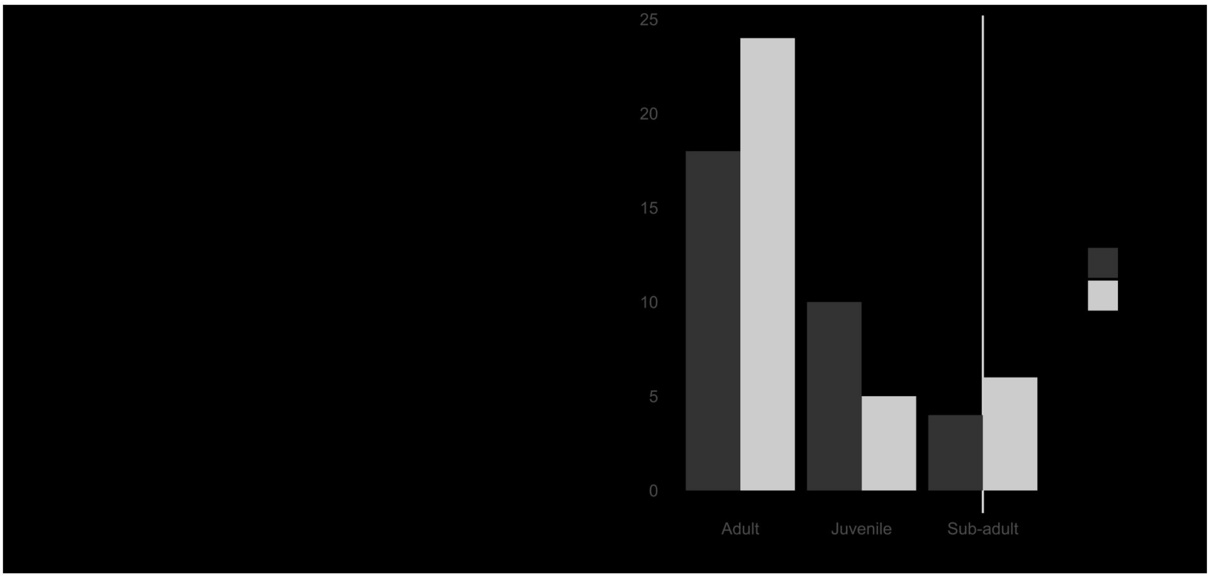

Figure 11: A) Age classes of living pangolins retrieved out of the trade in South Africa (July 2016 to October 2019), and B) age class further sub-divided into sex excluding "unknown sex" records.

4.2 Condition of recovered pangolins

4.2.1 Condition of pangolins retrieved

Twenty-seven cases were excluded where the general condition was unrecorded. There was no significant difference in the condition between sexes of pangolins found ($\chi^2(3) = 0.71$, $p = 0.870$; Fig. 12B). When ranking condition from good, average, poor to critical, there was no significant differences between the number of pangolins and the condition in which they have been retrieved, although very few were regarded as 'critical' (n = 7; 30.16%). ($\chi^2(3) = 6.39$, $p = 0.094$; Fig. 12A). There was uniform distribution between conditions relating from 'good' (n = 20;31.75%), 'average' (n = 19; 30.16%) and 'poor' (n = 17; 26.98%). (Fig. 12A). However, in ranking condition from optimal (good) to compromised (critical, poor and average), there was a significant difference between 'optimal' and 'compromised' individuals with far more animals being 'compromised' (68%) when retrieved out of the illegal trade ($\chi^2(1) = 9.29$, $p = 0.002$; Fig. 12A).

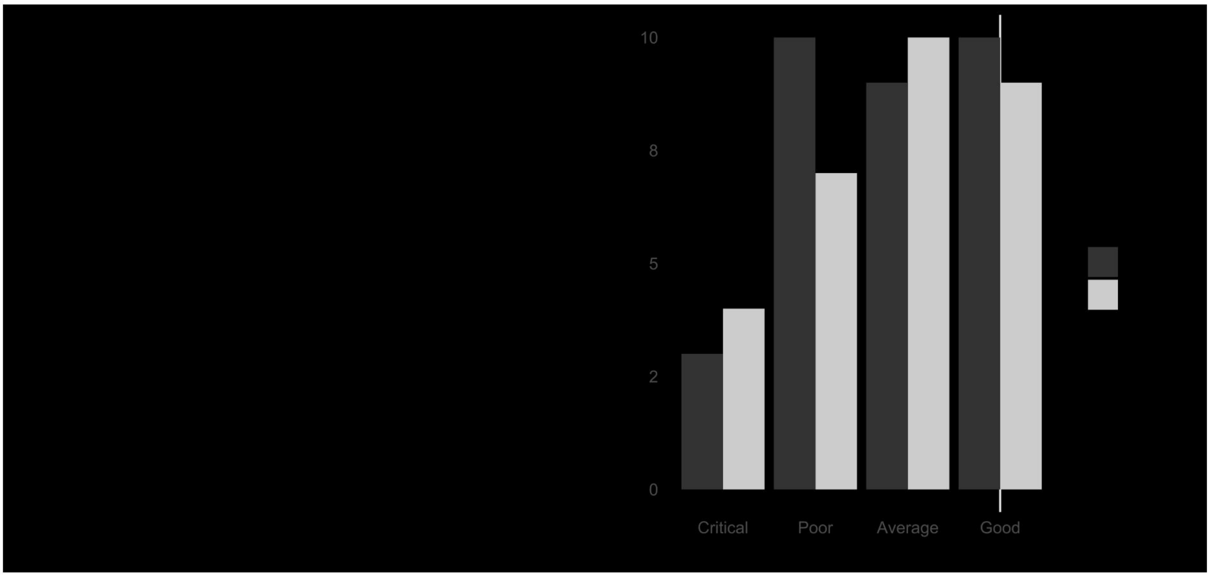

Figure 12: A) General health condition of living pangolins retrieved from the illegal trade in South Africa (July 2016 to October 2019). B) Sex of pangolins according to the condition in which they were retrieved.

4.2.2 Veterinary care and survival

A total of 60 (66.66%) pangolins, out of 90 living pangolins recovered, were confirmed to have received veterinary treatment. Veterinary treatment had a significant impact on the number of pangolins that survived ($\chi^2(1) = 9.6$, $p = 0.002$; Fig. 13), where 42 (70%) of treated pangolins survived to be discharged from the hospital and released.

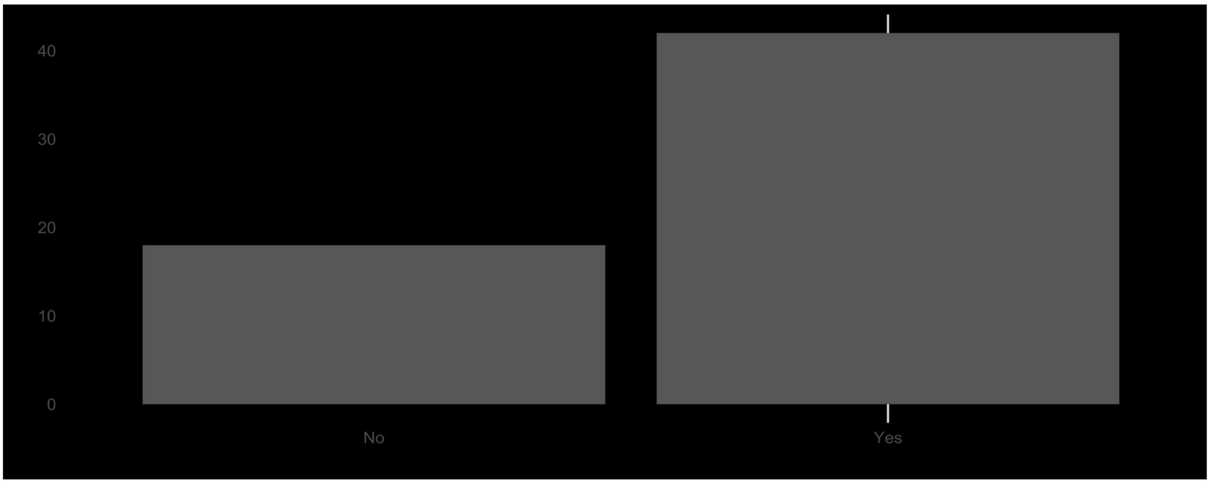

Figure 13: Pangolin survival rate following admission to hospital for veterinary care (July 2016 to October 2019).

4.3 Reintroduction and survival

4.3.1 Release protocols

During 2016, 8 pangolins were released, all of which followed the 'hard-release' protocol. In 2017, 17 pangolins were released with 16 (94.12%) cases being hard-releases and 1 (5.89%) case a soft-release. Further, a total of 28 pangolins were released during 2018, with 13 (46.43%) cases being hard-releases, and 15 (53.57%) cases soft-releases. Finally, during 2019, a total of 14 pangolins have been successfully released, where only 3 (21.43%) of these cases were hard-releases and the remaining 11 (64.71%) cases followed soft-release protocols. A total of 40 hard-releases and 27 soft-releases had been performed during this study (Fig. 14).

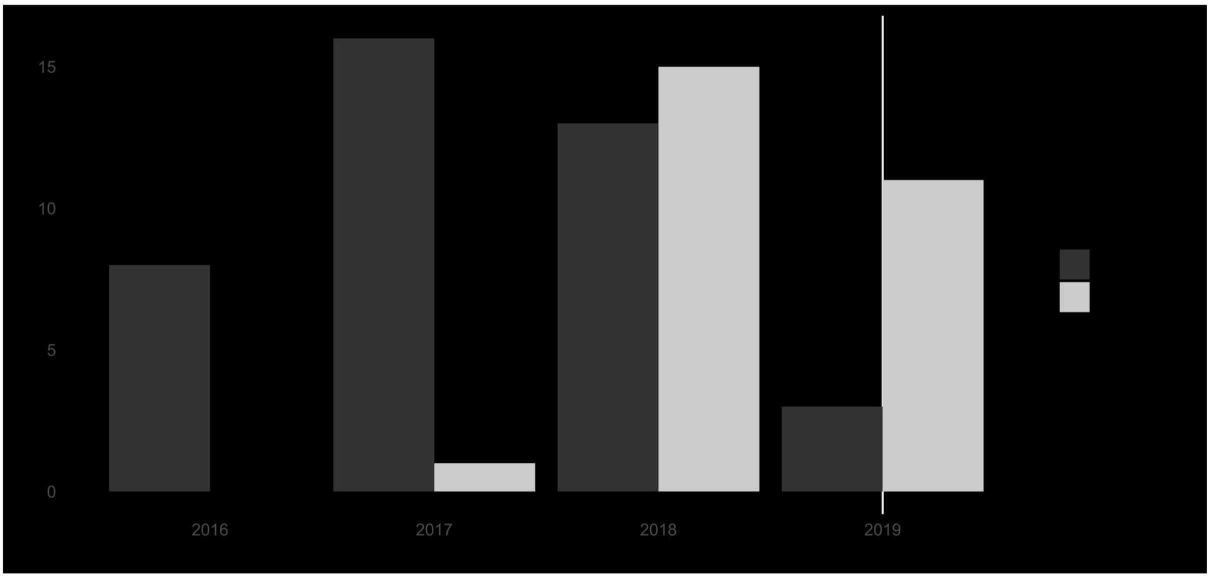

Figure 14: Annual recorded release protocols of pangolins in South Africa (July 2016 to October 2019).

4.3.2 Survival post-release

With regards to post release monitoring, there were 26 cases that could not be monitored successfully. All 26 of these cases were from hard-release circumstances and was thus excluded from further analysis.

From the remaining 41 pangolin cases, 14 (34.15%) were released as hard-releases where 5 (35.71%) died in the field and 9 (64.29%) survived. In the 27 (65.85%) soft-releases instances, 7 (25.93%) died and 20 (74.07%) survived (Table 2). There was no significant effect of release type on the number of pangolins that survived (p = 0.771; Fig. 15A). However, this result had a wide confidence interval and based on the odds ratio, the odds of soft-release survival was 0.64 (0.13 to 3.29) times higher than that of hard release.

A total of 21 (51.22%) of these pangolins were female, of which 15 (71.43%) survived and 6 (28.57%) died. The 20 (48.78%) remaining male pangolins that were released resulted in 14 (70%) survivors and 6 (30%) mortalities (Table 2). Sex had no significant difference in survival of released pangolins (p = 1; Fig. 15B).

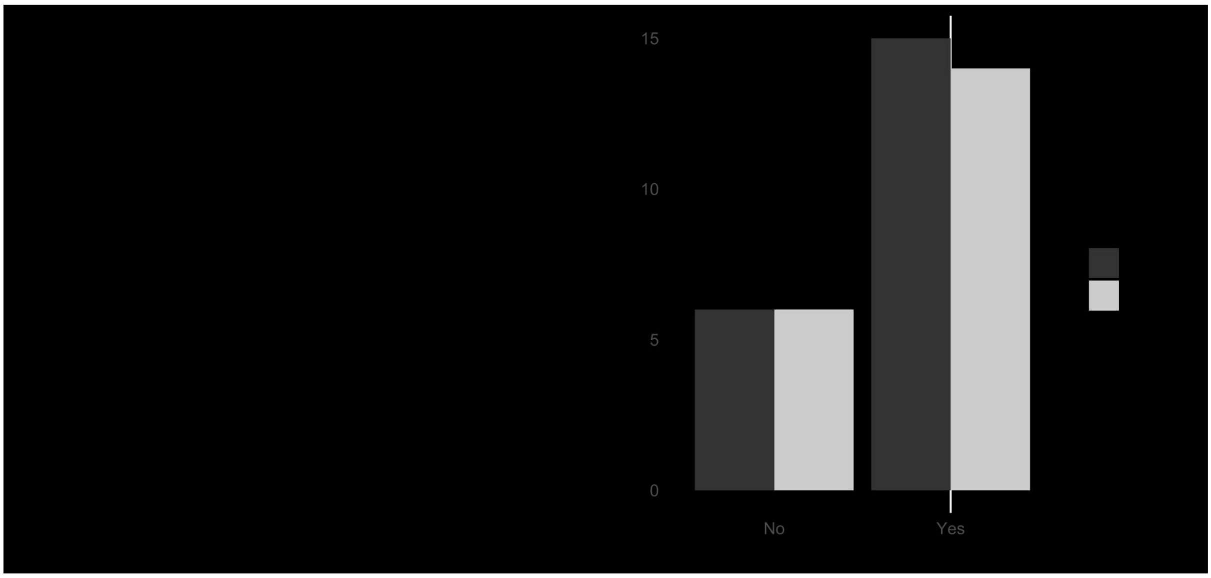

Figure 15: A) Confirmed survival and mortality numbers of released pangolins during July 2016 to October 2019, grouped according to release type and, B) according to sex.

Table 2: Pangolin releases (N = 41) where the last known status of the animals was successfully recorded (July 2016 to October 2019). Signal 'lost' indicates that the animal has moved beyond tracking range and was then regarded to have moved 'Off-site' and lost.

ID	Sex	Release date	Release Type	Last recorded visual	Observation time (days)	Last known status	Signal	Location
19	Female	27/10/2017	Hard	12/12/2017	46	Dead	-	On Site
26	Male	13/12/2017	Hard	23/01/2018	41	Alive	Lost	Off-site
28	Female	10/01/2018	Soft	14/01/2018	4	Dead	-	On site
30	Male	13/01/2018	Hard	13/03/2018	59	Dead	-	Off-site
34	Male	04/02/2018	Hard	22/05/2018	107	Alive	Lost	Off-site
35	Male	26/01/2018	Hard	10/02/2018	15	Alive	Lost	Off-site
38	Male	02/03/2018	Hard	22/03/2018	20	Alive	Lost	Off-site
40	Female	05/03/2018	Hard	26/03/2018	21	Alive	Lost	Off-site
44	Male	06/06/2018	Hard	08/06/2018	2	Dead	-	On site
46	Male	30/06/2018	Hard	13/08/2018	44	Alive	Lost	Off-site
47	Female	11/07/2018	Hard	05/11/2018	117	Alive	Lost	On site
48	Female	18/07/2018	Hard	21/07/2018	3	Alive	Lost	Off-site
49	Female	27/07/2018	Hard	03/08/2018	7	Dead	-	On site
50	Male	12/09/2018	Soft	13/09/2018	1	Dead	-	On site
51	Female	30/08/2018	Soft	17/09/2018	18	Alive	Lost	Off-site
52	Female	25/08/2018	Soft	19/10/2018	55	Alive	Lost	Off-site
53	Female	04/03/2019	Soft	26/03/2019	22	Alive	Lost	Off-site
54	Male	03/10/2018	Soft	05/12/2018	63	Alive	Lost	On site
55	Male	12/10/2018	Soft	22/10/2018	10	Dead	-	On site
56	Male	13/10/2018	Soft	11/12/2018	59	Alive	Lost	Off-site
59	Female	09/11/2018	Soft	29/10/2019	354	Alive	Active	On site
63	Male	03/11/2019	Soft	05/11/2019	2	Alive	Active	On site
64	Male	10/11/2018	Soft	01/12/2018	21	Alive	Lost	On site
67	Female	09/11/2018	Soft	24/08/2019	288	Alive	Active	On site
68	Male	19/02/2019	Soft	26/05/2019	96	Alive	Active	Off-site
69	Female	13/12/2018	Soft	21/12/2018	8	Dead	-	On site
70	Female	03/12/2018	Soft	09/09/2019	280	Alive	Active	Off-site
71	Male	31/12/2018	Soft	17/01/2019	17	Dead	-	On site
72	Female	10/03/2019	Soft	11/03/2019	1	Dead	-	On site
74	Female	19/04/2019	Soft	15/10/2019	179	Alive	Active	On site
75	Female	22/04/2019	Soft	25/04/2019	3	Alive	Lost	Off-site
78	Male	04/06/2019	Soft	10/11/2019	159	Alive	Active	On site
83	Female	04/06/2019	Soft	10/11/2019	159	Alive	Active	On site
87	Female	05/08/2019	Hard	07/08/2019	2	Dead	-	On site
88	Male	24/08/2019	Soft	26/10/2019	63	Dead	-	On site
89	Male	19/08/2019	Hard	20/08/2019	1	Alive	Lost	Off-site
93	Male	06/11/2019	Soft	10/11/2019	4	Alive	Active	Off-site
94	Male	06/11/2019	Soft	10/11/2019	4	Alive	Active	On site
95	Female	06/11/2019	Soft	10/11/2019	4	Alive	Active	On site
96	Female	06/11/2019	Soft	10/11/2019	4	Alive	Active	On site
98	Female	06/11/2019	Soft	10/11/2019	4	Alive	Active	On site

Examining survival probability, and the value of hard- and soft-release protocols, it is evident that the soft-release approach did yield a higher survival rate than the hard-release approach. This difference however, was not found to be statistically significant (Hazard Ratio 0.64, z = -0.77, p = 0.44; Fig. 16). The 14 hard-release cases were monitored between 1 and 117 days (Table 2), with a median survival of 63 days. Soft-release cases comprised of 27 individuals that were monitored between 1 and 354 days (Table 2), where no median could be calculated due to the survivorship curve never crossing below the 50% survival probability level (Fig. 13).

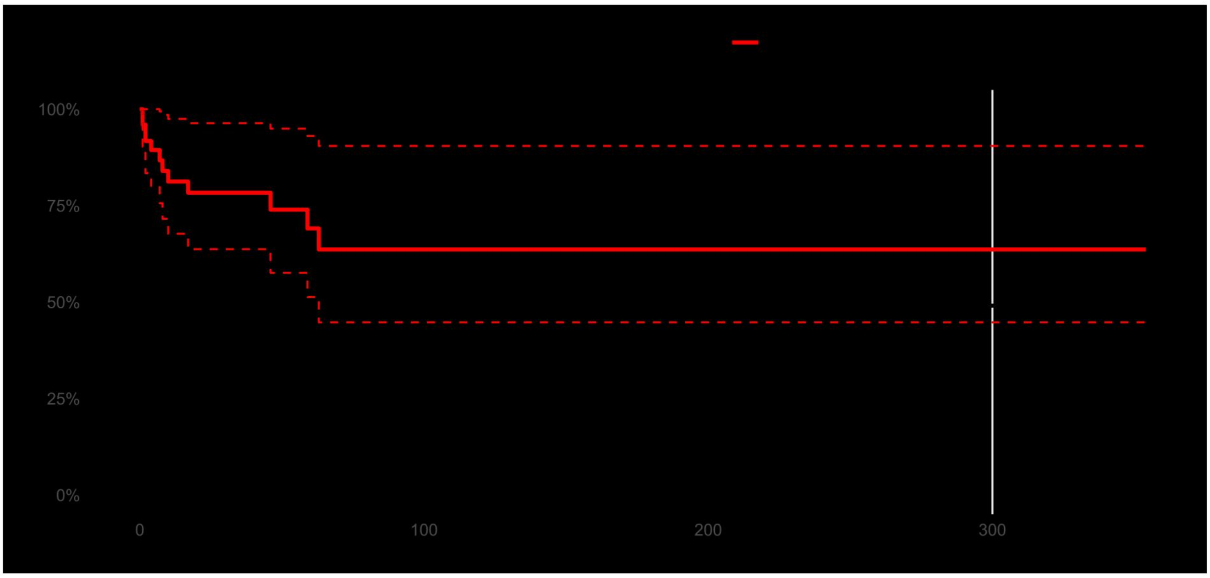

Figure 16: Predicted survival rate of pangolins from hard-release (N=14) and soft-release (N=27) protocols from July 2016 to October 2019. Dashed lines represent 95% confidence intervals respectively.

4.4 Post-release monitoring and observation

4.4.1 Confirmed mortalities

A total of 12 mortalities post-release were confirmed during this study (Table 2). One (1) (8.33%) of these cases was of unnatural causes and 4 (33.33%) of the mortalities was due to natural causes. The remaining 7 (58.33%) mortalities was due to trade related stress (Table 3). Reason for death had no significant effect on the number of mortalities of pangolins ($\chi^2(2)$ = 4.5, p = 0.105; Fig. 17). The majority of pangolins (n = 10; 83.33%) that did perish, had received veterinary care prior to release (Table 3).

Table 3: Confirmed mortalities of released pangolins and the classification of each reason for death (July 2016 to October 2019).

ID	Vet care before release	Reason for death (Observations)	Classification
19	Yes	Predation. Honey badger (*Mellivora capensis*)	Natural
28	No	Ingested wasp	Natural
30	No	Old Age	Natural
44	Yes	Declining condition	Trade related
49	Yes	Declining condition	Trade related
50	Yes	Declining condition	Trade related
55	Yes	Killed by Elephant (*Loxodonta africana*)	Natural
69	Yes	Declining condition (Heart failure)	Trade related
71	Yes	Declining condition (Pancreatitis)	Trade related
72	Yes	Electric fence line	Unnatural
87	Yes	Declining condition (Organ failure)	Trade related
88	Yes	Declining condition	Trade related

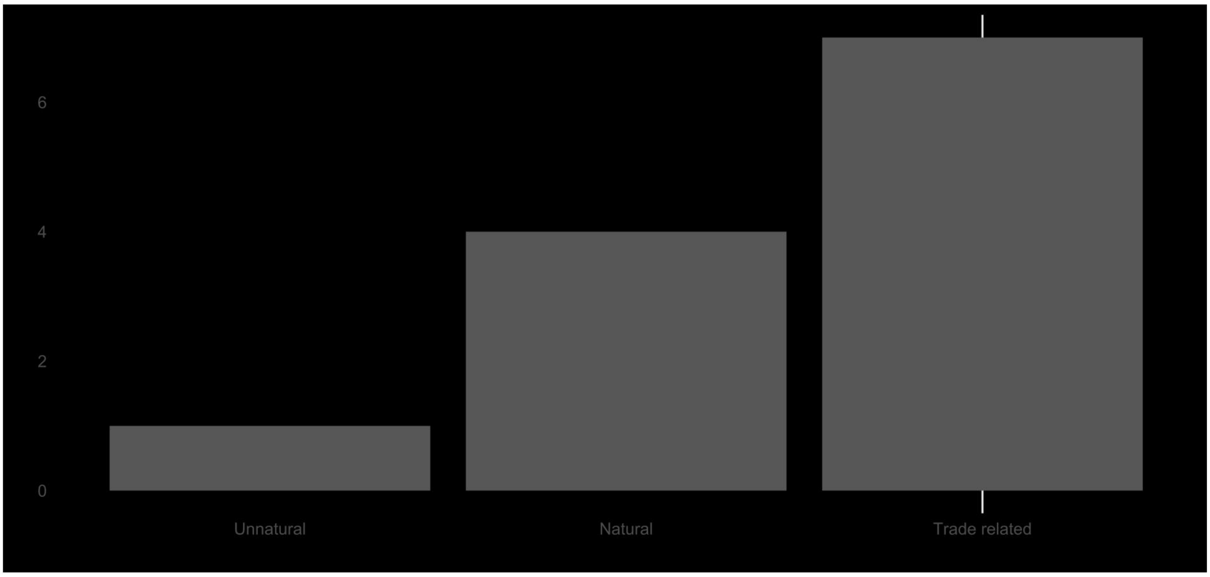

Figure 17: Confirmed mortalities of pangolins post-release arranged according to classification for death (July 2016 to October 2019).

4.4.2 Post-release movement

Of the 41 pangolins which was successfully monitored, a total of 17 (41.46%) pangolins moved off-site (Table 2). Observations showed that the majority, 11 (64.71%), of these pangolins moved off-site within the first month of release. The remaining 6 (35.29%) pangolins moved off-site between two to three months post-release (Figure 18). The duration (in months) post-release was significant ($\chi^2(2) = 8.941$, $p = 0.011$; Fig. 18) in that far more pangolins moved off site within the first month (four weeks) following release.

Of the pangolins that moved off site; 10 (58.82%) were male and 7 (41.18%) were female (Fig. 19A). There was very little difference in this off-site behaviour between 'hard' and 'soft' release types where 9 (52.94%) of these cases were recorded as hard-release and 8 (47.06%) as soft-release (Fig. 19B). Neither sex (p=1; Fig. 19A), nor release type (p=1; Fig. 19B) was significant in terms of the length of time (months) pangolins moved off site.

Figure 18: Number of pangolins (N=17) moving off-site according to duration (months) following release.

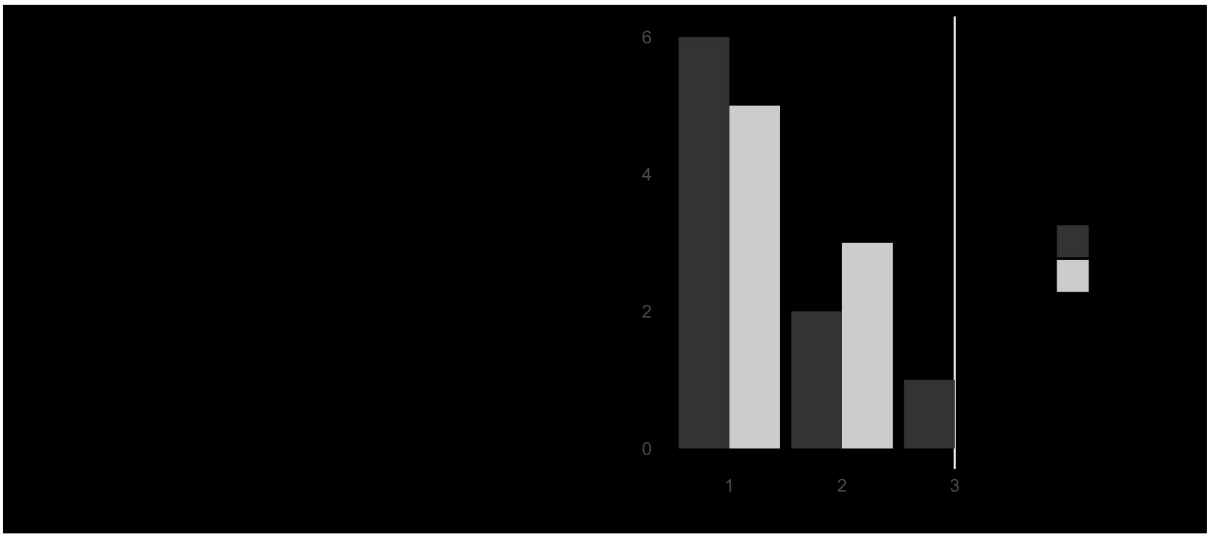

Figure 19: Number of pangolins which have moved off site according to duration (months) following release, and according to A) sex of pangolins and B) release type.

Within the primary release area, located in the Northern Limpopo Province, 11 pangolins had been released; six (6) females and five (5) males.

There was a total of five (5) confirmed mortalities where the majority of deaths occurred within three (3) weeks following release. An exception to this was a single adult female pangolin whose movement could be monitored for up to 59 days before its death. This individual could only be monitored using VHF radio telemetry (Fig. 20).

Only five (5) of the remaining six (6) living pangolins could be monitored successfully for a period exceeding one month. One of these pangolins was fitted only with a VHF radio tracking system (Fig. 21), where the remaining pangolins were fitted with both VHF and satellite tracking systems (Fig. 22, 23, 24 & 25).

All pangolins monitored within this release area moved off-site except for one adult male (Fig. 22) and one adult female (Fig. 23). The female, however, has subsequently moved off-site during the compilation of this dissertation.

Of the six individual pangolins monitored in the core release site of northern Limpopo Province, the number of days they were monitored ranged from 55 to 280 and the total area they ranged (MCP) was from 1 km^2 up to 369 km^2 with intense core ranges (kernel 50) ranging from 0.69 km^2 to 125 km^2 (Table 4).

Table 4: Calculated minimum convex polygon (MCP), 95% kernel (KR 95) and 50% kernel (KR 50) ranges size. Pangolin ID corresponds with Table 2 entries and relevant movement figures.

ID	Sex	Number of days monitored	Number of points collected	MCP (km^2)	KR 95 (km^2)	KR 50 (km^2)
30	Female	59	15	30.79	249.54	67.96
52	Female	55	58	1.08	2.49	0.69
54	Male	63	209	7.93	6.37	0.99
59	Female	354	166	77.32	132.56	27.77
68	Male	96	245	12.62	5.51	0.95
70	Female	280	360	369.87	645.48	125.74

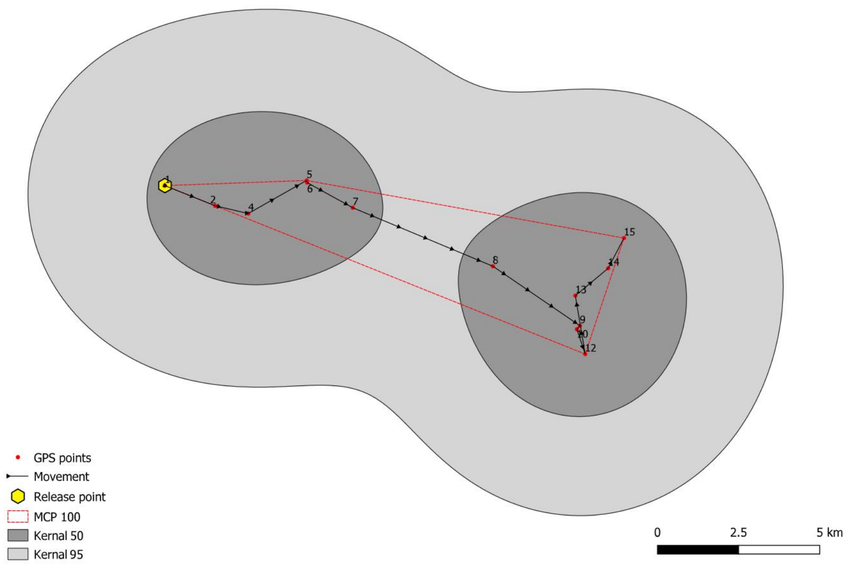

Figure 20: Movement range and minimum convex polygon (MCP) estimates for an adult female pangolin, Tolwe (ID: 30), post-release. This individual was monitored for a total of 59 days where a total of 15 GPS points had been logged using VHF radio tracking. Hereafter, the pangolin died, probably due to old age. Release site located in northern Limpopo Province, South Africa.

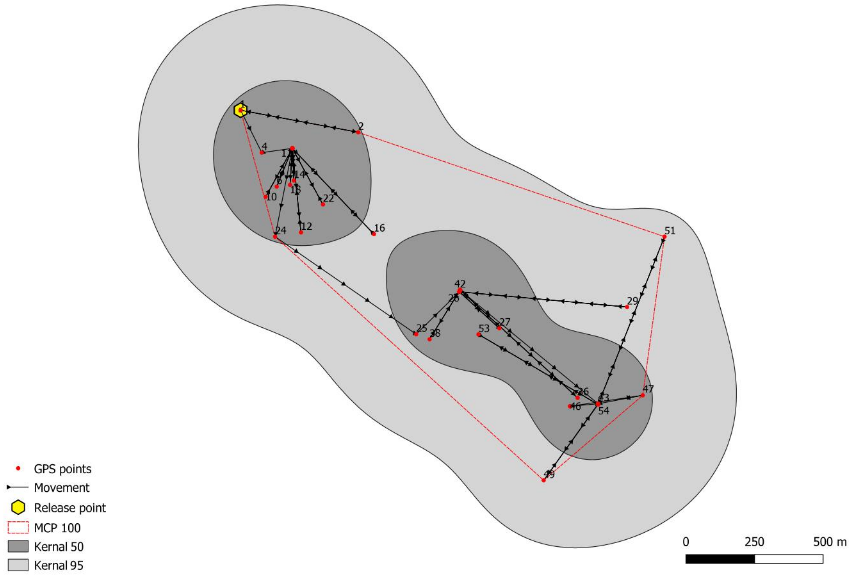

Figure 21: Movement range and minimum convex polygon (MCP) estimates for an adult female pangolin, Khwara (ID 52), post-release. This individual was monitored for a total of 55 days where a total of 58 GPS points has been logged using VHF radio tracking. Hereafter the pangolin had moved off-site. Release site located in northern Limpopo Province, South Africa.

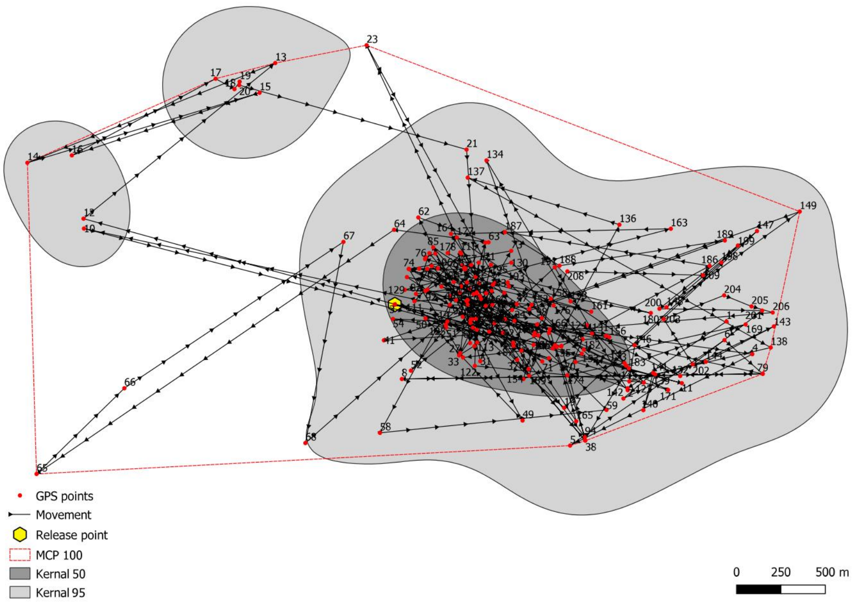

Figure 22: Movement range and minimum convex polygon (MCP) estimates for an adult male pangolin, Khufu (ID 54), post-release. This individual was monitored for a total of 63 days where a total of 209 GPS points had been logged using both satellite tracking and VHF radio tracking. Hereafter, the pangolin still remained on site. Release site located in northern Limpopo Province, South Africa.

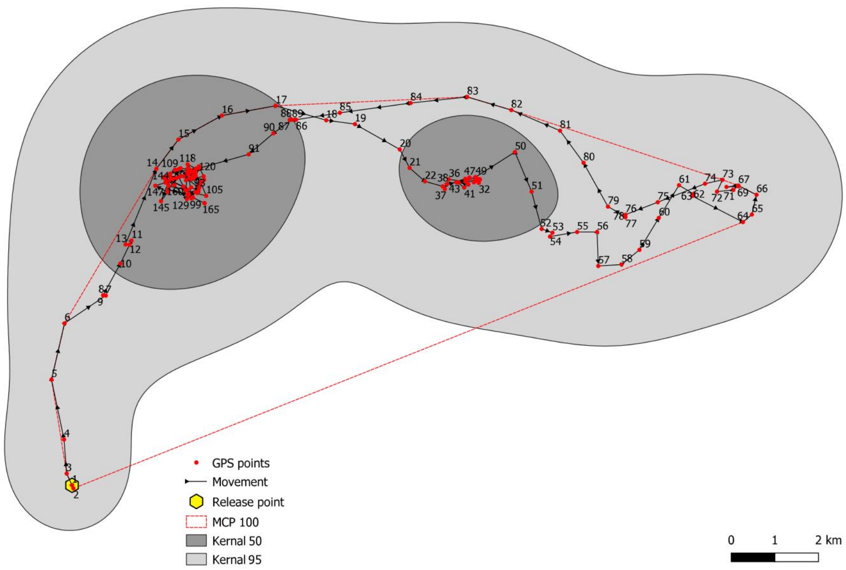

Figure 23: Movement range and minimum convex polygon (MCP) estimates for an adult female pangolin, Mumalia (ID: 59), post-release. This individual was monitored for a total of 354 days where a total of 166 GPS points had been logged using both satellite tracking and VHF radio tracking. Release site located in northern Limpopo Province, South Africa.

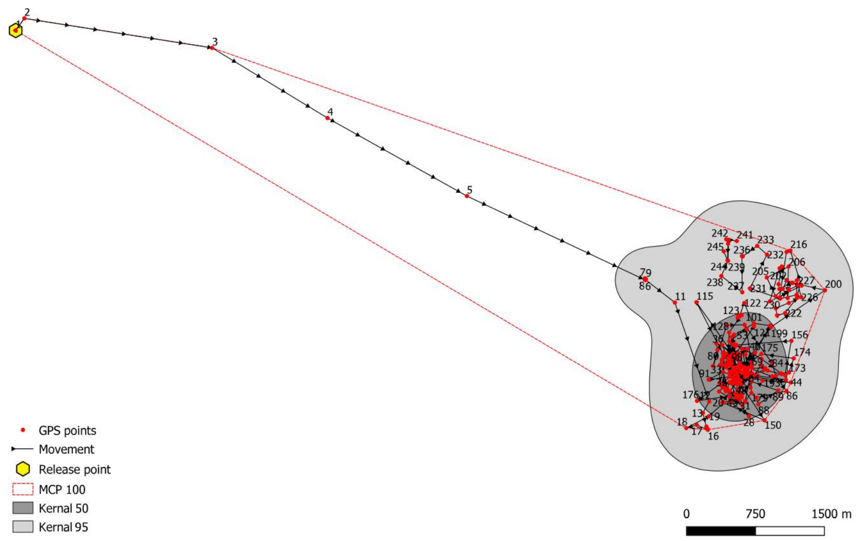

Figure 24: Movement range and minimum convex polygon (MCP) estimates for a young adult male pangolin, River (ID: 68), post-release. This individual was monitored for a total of 96 days where a total of 245 GPS points had been logged using both satellite tracking and VHF radio tracking. Release site located in Northern Limpopo Province, South Africa.

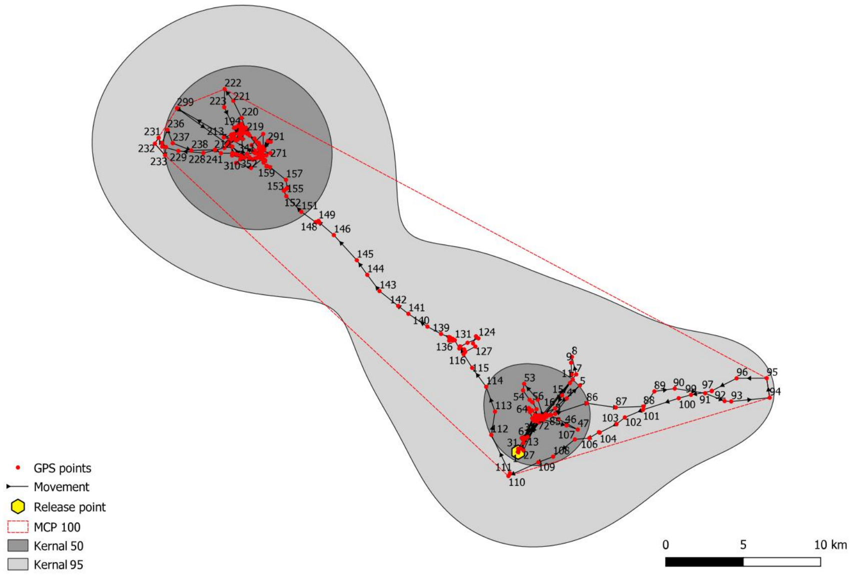

Figure 25: Movement range and minimum convex polygon (MCP) estimates for an adult female pangolin, Terrell (ID: 70), post-release. This individual was monitored for a total of 280 days where a total of 360 GPS points had been logged using both satellite tracking and VHF radio tracking. Release site located in northern Limpopo Province, South Africa.

5. Chapter Five: Discussion

5.1 Trade in South Africa

Since the initiation of this study, an immediate challenge was the substantial lack in historical data regarding pangolin confiscations, relevant demographic information and the subsequent release data that could have been documented. Sufficient record keeping had only started in 2016, with content accumulating and being refined with time since then.

Nevertheless, even with limited available data, interesting observations could still be made and relevant hypotheses could still be drawn.

5.1.1 Pangolins retrieved from the trade

Based on international records and trends, there has been an exponential increase in the illegal trade in pangolins and pangolin body parts in recent years (APWG, unpublished data). The hypothesis was drawn that South Africa would show similar results with an annual increase in the illegal trade of pangolins in this country increasing over time. This was indeed the case, as results indicated a significant difference between years and, as supported by the NPA annual report in 2018, poaching and smuggling of pangolins seems to be escalating in South Africa in recent years (NDPP, 2018).

It could be argued that this increase in arrests can be attributed to other factors, such as improved awareness from the public and local law enforcement, but this alone cannot be responsible for such a significant rise in confiscations. An increase in wildlife crime involving a wide range of species has been well documented in South Africa (NISCWT, 2017). This issue will only be addressed effectively through improved education surrounding the topic, and when punishment of illicit trade outweighs its current alluring benefits (Abotsi *et al.*, 2016).

Further, since previous research suggest that male pangolins may disperse over greater distances than females (Heath & Coulson, 1997a; Pietersen *et al.*, 2014a) and they may even have larger home ranges (Heath & Coulson, 1997a), the hypothesis was made that males may also then be more likely to be encountered by poachers, and thus more likely to be recovered from the illegal trade. A recent study on the Taiwanese pangolin (*Manis pentadactyla pentadactyla*) similarly suggest that male pangolins are more susceptible to human encounters due to increased activity and larger home ranges (Sun *et al.*, 2019). The results obtained in this study, however, did not support this hypothesis, but rather the idea that male and female *S. temminckii* are both equally susceptible to the threat of poaching. Further research on the behaviour and distribution between sexes is required to further explore the possible reasons behind these findings.

5.1.2 Provincial data

Although *S. temminckii* is the most widespread pangolin species in Africa (Pietersen *et al.*, 2016), their local distribution in South Africa is only limited to the far north-eastern border with Mozambique, far northern border with Zimbabwe and the far north-western border with Botswana and Namibia. As a result, the species only occurs in the Northern Cape, North West, Limpopo, Mpumalanga and the KwaZulu-Natal Provinces (IUCN, 2019, Pietersen *et al.*, 2020). Based on this distributional range, it was expected that the majority of pangolin confiscations would also take place within these provinces. However, the province with the second highest confiscations (Gauteng) falls out of the species natural distribution range.

The province with the highest confiscations was Limpopo Province which falls within this species natural distribution and is also the province that has borders with Zimbabwe and Mozambique. In the majority of cases where successful arrests were made, foreigners from both these countries have been directly involved in this trade (APWG, unpublished data, pers. obs.) and both these provinces harbour the largest population of illegal migrants from both Mozambique and Zimbabwe. Additionally, an increase in cross-border smuggling of live pangolins have also been acknowledged by the NPA (NDPP, 2018). Wildlife crime is well documented within these countries, especially in the case of Zimbabwe, who's wildlife has been significantly impacted by corruption and an unstable economy since the year 2000 (Gandiwa *et al.*, 2013).

5.1.3 Seasonal data

Home range studies on this species of pangolin undertaken in the Kalahari (Pietersen *et al.*, 2014a) suggest that home range size and activity may change between seasons. It therefore stands to reason that poaching frequency, and consequently confiscations, will also then be affected in times when pangolins are more active and become more visible.

Pietersen *et al.* (2014a) tracked two Temminck's pangolins, one male and one female, successfully for a long enough period to compare their distribution behaviour between seasons. They found that the female pangolin covered a larger area during summer than the male, and oppositely the male covered a larger area in winter than the female. Based on their observations, the expectation in this study was that confiscation of male and female pangolins might differ significantly between seasons.

Results from this study did indicate a significant difference in pangolin seizures between seasons, supporting the notion that pangolin behaviour and distribution are meaningfully affected by seasonal conditions. Contrary to expectations though, there was no significant difference between the amount of female and male pangolins confiscated between seasons. Assuming that confiscations are influenced by pangolin distribution and activity, these finding then support the idea that male and female pangolins share more similar behaviour throughout seasons, and both sexes are then equally susceptible to the threat of poaching throughout the year.

The natural distribution of *S. temminckii* in southern Africa falls primarily within the Savannah biome (Laakso *et al.*, 2013) which has its rain season over the summer from November to March (Rutherford & Powrie, 2006). During this time, and with increased precipitation, the foliage and grass layer will also then be at its most dense and inhibit visibility. In contrast, Winter and Spring seasons fall during a drier period, with more sparse vegetation and thus improved visibility. As evening temperatures decrease during the dry winter period (Rutherford & Powrie, 2006), *S. temminckii* have been known to adapt and embrace a more diurnal behaviour (Pietersen *et al.*, 2014a; personal observation), which may increase the probability of encounters with humans. Field experience during this study has shown that tracking and monitoring of pangolins during the dry season was undoubtedly less demanding than when compared to the wet season. It stands to reason then that poachers will also have less difficulty to pursue these animals during more dry and favourable conditions. These factors may contribute as to why pangolin confiscations increase after the Summer season and peak during Spring, as the odds of poaching success may increase with improved visibility. To fully understand seasonal behaviour of *S. temminckii* and what role it may play in in the illicit trade of this species, further long-term studies are required on habitat use, dietary preferences and distribution patterns.

5.1.4 Demographics of confiscated pangolins

The results of this study clearly indicate that the majority of pangolins retrieved from the trade fall within the adult age group. A possible explanation behind this could be that a difference in behaviour and distribution might make them more vulnerable targets to being poached. As chance encounters with such a scarce species is extremely low, one cannot associate these results to the animal's movement alone. It has been well documented that both male and female Temminck's pangolins do establish and hold home ranges (Heath & Coulson, 1997a; Pietersen *et al.*, 2014a). Studies further indicate that adults have been found to have larger home ranges and to use more burrows than their younger counterparts (Heath & Coulson, 1997a). It is understandable that an increase in burrow use throughout a growing home range or territory, may increase the odds of a pangolin being discovered by poachers who regularly hunt for wildlife by inspecting known burrows. In addition, larger animals may be more sought after as they could be perceived to be more valuable in the illegal trade as they proportionally hold more meat and have larger heavier scales.

It is important to take into account that the data presented in this study only accounts for living pangolins that have been confiscated from the illegal trade. These finding could be an indication that younger pangolins may go through the trade unnoticed, or even that these age groups are more sensitive to the stressful conditions within the trade and thus prone to increased mortalities. Further research on pangolin mortalities within the trade will be required to determine if the demographics of the confiscated pangolins do accurately represent that of poached pangolins.

Further, findings did indicate that there have been slightly more adult male pangolins confiscated than females, and inversely more female juveniles than males. These differences, however, were not significant to make any reliable conclusions, again supporting the notion that both sexes are equally susceptible to the threat of poaching regardless of conditions, circumstances or behaviour.

5.1.5 Condition of recovered pangolins

The majority (68.25%) of pangolins that were retrieved from the illegal trade during this study were assessed to be in a compromised, or less than optimal, condition with no variation between sexes. Due to the harsh conditions in which these animals are kept within the trade, pangolins have been known to develop several heath complications many of which are related to respiratory disorders, gastrointestinal ulceration, organ failure and general susceptibility to illness as a result of a compromised immune system (Wicker *et al.*, 2020).

The severity of this issue is further evident in the losses experienced within veterinary hospital care. Almost a third of the pangolins that have been retrieved from the illegal trade during this study, which received veterinary treatment, could not recover and died before release. During the period of this study, a major concern that was the lack of experienced veterinarians who had exposure to treating pangolins was severely lacking in this country (personal observation) and, prior to 2017, the large majority of pangolins retrieved out of the illegal wildlife trade were simply release immediately without a veterinary inspection (APWG, unpublished data). In a number of cases where pangolins did receive treatment, poor knowledge in pangolin health care and treatment also contributed to potentially unnecessary mortalities.

5.2 Reintroduction and survival

5.2.1 Release protocols

APWG has played a major role in the recovery and reintroduction of pangolins from 2016 onwards. As knowledge and experience on the species improved over time, the APWG together with JWVH adopted a new facilitated release, or "soft-release" protocol of which this study has been a substantial focus. The soft-release protocol was adopted initially in the onset of 2017 and has become the preferred method of release by these organizations (Wright & Jimerson, 2020).

The APWG further acts as consultants for SAPS and DEA regarding pangolin recovery and reintroduction. The soft-release approach has therefore now become the default release process across South Africa. Collaborations such as these have proven to be a valuable asset for pangolin conservation in combating poaching and improving care and release procedures (Shepherd *et al.*, 2017; Sun *et al.*, 2019).

Together with habituating the animal to its environment, the soft-release protocol provided us with the unique opportunity to observe the pangolins in the field and gain better insight on their behaviour. These observations not only assist with the release itself, but further contributes to much needed behavioural research for pangolins released after being retrieved out of the illegal wildlife trade (Pietersen *et al.*, 2016). Direct observation further proved invaluable to identify behaviours and signs that can act as warning indications of a pangolin that is compromised or one that has not settled or experiencing undue stress. With each release each pangolin would behave differently as so new knowledge was gained to the pool of knowledge that could be applied in future cases. As beneficial as this approach may be, it is important to take into account that monitoring should not be invasive as this could also place unnecessary stress on the animal if performed incorrectly or recklessly. In every case, care needs to be taken to reduce stress-factors as much as possible.

Even though the soft-release method may not always be necessary, or even beneficial, there are very few experienced individuals in South Africa to make such an assessment once presented with a recovered pangolin. Therefore, having soft-release as a default approach is still a preferred advancement, as it forces the involvement of more experienced individuals. Further assessment can then be made more accurately on a case to case basis.

Every successful confiscation should be viewed as an opportunity to learn more about these animals, their health and their environment.

5.3 Survival

Soft-release procedures are not uncommon when reintroducing wildlife back into their natural environment. This approach has proven to improve the survival rates of several other species such as the smooth green snake (*Opheodrys vernalis*), the hazel dormouse (*Muscardinus avellanarius*) the American black bear (*Ursus americanus*), and the Canada lynx (*Lynx canadensis*) (Bright & Morris, 1994; Devineau *et al.*, 2011; Eastridge *et al.*, 2001; Sacerdote-Velat *et al.*, 2014). Even so, there have also been studies which indicate that soft-release has little to no positive effect on survival, such as with the eastern grey kangaroo (*Macropus giganteus*) and the tawny owl (*Strix aluco*) (Griffiths *et al.*, 2010; Campbell & Croft, 2001). However, few studies exist for those species that have been part of illegal wildlife crime trade and this has a marked impact on both the physical and mental well-being on these individual animals that require a more intensive rehabilitation process.

In comparing release methods for the Temmick's pangolin, survivorship results from this study indicate that the soft-release method did indeed yield a higher survival probability than hard-release. However, these findings could unfortunately not be confirmed as statistically significant due to the limited sample size as a result of the very recent implementation of the soft release protocol. In saying that, this study supports the current standing in South Africa in which the soft-release process has been accepted as the standard approach to releasing pangolins back into the wild and should be tested with other species of both African and Asian pangolins. These protocols are still relatively recent and should be further refined as knowledge and experience improve on the process, always aiming to reduce anthropogenic stress where possible. Current knowledge on pangolin health and survival is limited (Wicker *et al.*, 2020) and these facilitated and monitored release methods could contribute to much needed *in situ* and *ex situ* management strategies for the Order.

5.3.1 Mortalities

Electric fence lines used as standard practice in the game ranching industry in much of southern Africa were initially presumed to be a substantial threat regarding Temminck's pangolin release procedures (Challender *et al.*, 2014; Pietersen *et al.*, 2014b). Within this study site, these fences can be regarded as reasonably abundant and difficult to avoid as observations clearly indicated that released pangolins often moved beyond the initial release site which was first assessed as "safe". This study clearly demonstrated that several pangolins did traverse these boundaries, with only a single confirmed mortality due to an electrical fence line surrounding a sable antelope (*Hippotragus niger*) breeding camp. Past studies have also observed territorial males successfully traversing electric fences on a regular basis without hindrance (Pietersen *et al.*, 2014b). Although these findings seem to dismiss the hazard of electric fence lines, it should rather be interpreted that not all types of electric fence lines may pose the same threat to pangolin movement. Natural threats, such as predation or environmental conditions, were also recorded, but these factors were regarded as unavoidable. Nonetheless, each mortality did provide us with a larger risk-factor database when assessing current and future release sites and regions.

Even after these animals were discharged from veterinary treatment, the primary cause of mortalities remained related to trade-induced stress or trauma. This was deduced from the vast majority of pangolin mortalities associated with a compromised condition and illness that could be directly associated to their experience within the illegal trade such as pneumonia. These observations further emphasize the susceptibility these animals have towards the stressful conditions they experienced within the illegal wildlife trade and emphasises the necessity for post release monitoring.

The post release survival and mortality outcome from this study questions previous claims of 100% release and reintroduction success of the same pangolin species in nearby Zimbabwe (Tikki Hywood Trust, unpublished data). These claims seem highly unlikely as a number of mortalities do occur some months post-release, further emphasizing the importance of a monitored post-release for an extended period of time.

5.3.2 Monitoring and movement

During the course of this study it was found that the behaviour and movement of released pangolins was difficult to predict. Tracking and monitoring was especially difficult as there were several cases where tracking systems failed, tags dropped off, the animal moved beyond tracking range, or the animals were lost due to human error. Multiple pangolins even moved off-site after it initially seemed that they have settled within an area.

In cases where animals could be tracked successfully for longer periods of time, distribution and ranges varied greatly. These findings give a new understanding of pangolin movement after they have been released into a new area. With regards to pangolins that have been retrieved from the trade, these findings suggest that long term monitoring will be required to accurately assess whether these pangolins establish true home ranges, and in what time frame they would do so. This time frame would exceed the time period of 85 days as found by

Heath and Coulson (1997b), where a young pangolin which was retrieved from a poacher apparently established a home range within this time.

VHF radio tracking is currently the most used system on *S. temminck*ii (Willcox *et al.*, 2019). It has proven to be effective in getting visual on the pangolins, but unfortunately once these animals move beyond tracking distance it is very difficult to locate them again. This method of tracking made gathering of consistent data difficult, as a visual or data points was not always guaranteed. Therefore, data can be limited for analysis.

As the satellite tracking system became available it provided a much-needed insight to the different movement patters one can expect from these animals. Many pangolins moved off-site or beyond tracking range which provided much needed insight on what considerations need to be made when releasing a pangolin into an area. This was especially true in the case of Terrell (ID: 70), which was the first pangolin, released from the illegal trade, to move off-site with a functional satellite tracking system. This case provided a completely new view on what distances these animals can move and in what short time periods they can do so.

It was found that after a pangolin has been released, the first month of monitoring required the most dedication and diligence. It was during this time period where the majority of pangolins moved off-site and where signal and data was lost. The tracking system used does play an important role in monitoring, but a certain level of commitment is required from release areas and tracking teams to successfully gather reliable data.

The current data collected underlined the importance of using a suitable and reliable tracking system, especially in the case when dealing with unpredictable behaviour. There is still room for improvement on tag design, durability, and cost efficiency with regards to the monitoring of pangolins.

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5.4 Conclusion and recommendations

The large increase in the illegal trade of pangolins both globally and in South Africa is a growing concern for the entire Order. It is imperative that this illegal trade in Temminck's pangolin be mitigated or at least inhibited, and procedures as to the treatment, rehabilitation and release of this threatened species be put in place to combat the species decline.

Communities, private organizations, non-profit organizations and government spheres of policing and conservation, all played a pivotal role in the confiscation, treatment and reintroduction of pangolins in South Africa. These types of collaborations should be encouraged to help develop and establish effective standard operating procedures, and set an example for other pangolin range states further into Africa and in Asia.

There was a noticeable lack in experienced individuals who can assess the condition of pangolins, and facilitate their release. This contributed to increased mortalities of pangolins placed into release programs in a number of situations. Furthermore, this was also evident in the veterinary care of pangolins retrieved from the illegal wildlife trade, or the complete lack of veterinary care and housing facilities in a large majority of historical cases. Trained individuals and equipped facilities are particularly lacking in areas suitable for pangolin release and needs to be addressed with a matter of urgency. It is further disturbing that these procedures are only in place in a small number of organisations globally. A global standard should be adopted and rolled out through a recognised conservation body such as the IUCN SSC Pangolin Specialist Group.

During the course of this study, a number of important variables discovered have contributed to the successful release of trafficked pangolins. One important aspect was the vast distances these animals can cover from their original release site, where a single medium-sized conservation area cannot be regarded as suitable if the surrounding areas are unsuitable. As such, it is vital to ensure that these surrounding areas are not just ecologically suitable, but also that the local resident communities do not pose a threat to the species. To ensure tong term sustainability, local communities and landowners should be incorporated into local pangolin reintroduction projects.

Failure of tracking equipment, particularly satellite tracking, was another challenge encountered in the field. For reliable (non-invasive) data collection on pangolins, more cost-effective and durable designs are desired. Both satellite tracking technology combined with a VHF system is recommended when working with this species.

Although the soft-release procedure was not found to be statistically significant, we still strongly recommend its use. *S. temminckii* is an endangered species and the animals retrieved out of the illegal trade have suffered extreme trauma. A facilitated release process offers numerous benefits for the animal and provides further opportunities to learn more about a species and what can be done to aid in its conservation.

From the confiscation, to treatment, to reintroduction, and even post-release monitoring, all levels of contact with these animals needs to be performed with great care as not to be too invasive. The continuous systematic assessment of protocols together with training of sufficient law enforcement, veterinarians and researchers is recommended to establish and improve all confiscation, rehabilitation and release procedures.

This study was a first of its kind in investigating the release procedures involved in pangolins retrieved out of the illegal wildlife trade, and laid the foundation for post-release monitoring procedures. A final suitable and successful protocol to enhance the survival of these animals has now been initiated, but still lacks refinement through long-term monitoring and a greater sample size. Additional factors to consider are those played by various release habitat types, changes in season and climate, and the vast array of prey species pangolins feed on.

6. References

Abdelaal, M. M. A., & Zakria, S. H. E. A. (2015). Modeling survival data by using Cox Regression Model. *American Journal of Theoretical and Applied Statistics*, *4*(6), 504.

Abotsi, K. E., Galizzi, P., & Herklotz, A. (2016). Wildlife Crime and Degradation in Africa: An Analysis of the Current Crisis and Prospects for a Secure Future. *Fordham Environmental Law Review*, *27*(3), 394-441.

APWG (2019). African Pangolin Working Group: registered non-profit conservation organisation, www.pangolin.org.za

Baker, F. (2014). *Assessing the Asian industry link in the intercontinental trade of African pangolins, Gabon* (Doctoral dissertation, Department of Life Sciences, Silwood Park, Imperial College London).

Barron, D. H. (2015). How the illegal wildlife trade is fuelling armed conflict. *Geo. J. Int'l Aff.*, *16*, 217.

Biggs, D., Courchamp, F., Martin, R., & Possingham, H. P. (2013). Legal trade of Africa's rhino horns. *Science*, *339*(6123), 1038-1039.

Blundell, A. G., & Mascia, M. B. (2005). Discrepancies in reported levels of international wildlife trade. *Conservation Biology*, *19*(6), 2020-2025

Boakye, M. K., Pietersen, D. W., Kotzé, A., Dalton, D. L., & Jansen, R. (2015). Knowledge and uses of African pangolins as a source of traditional medicine in Ghana. *PLoS One*, *10*(1).

Bright, P. W., & Morris, P. A. (1994). Animal translocation for conservation: performance of dormice in relation to release methods, origin and season. *Journal of Applied Ecology*, 699-708.

Calenge, C. (2011). Home range estimation in R: the adehabitatHR package. *Office national de la classe et de la faune sauvage: Saint Benoist, Auffargis, France*.

Campbell, L., & Croft, D. B. (2001, July). Comparison of hard and soft release of hand reared eastern grey kangaroos. In *Veterinary conservation biology, wildlife health and management in Australasia, proceedings of international joint conference. Sydney: Taronga Zoo* (pp. 173-180).

Campera, M., Brown, E., Imron, M. A., & Nekaris, K. A. I. (2020). Unmonitored releases of small animals? The importance of considering natural dispersal, health, and human habituation when releasing a territorial mammal threatened by wildlife trade. *Biological Conservation*, *242*, 108404.

Challender, D., Baillie, J., & Waterman, C. (2014). c. *IUCN SSC Pangolin Specialist Group Conservation Action Plan, Zoological Society of London, London*.

Challender, D. W., Waterman, C., & Baillie, J. E. (2014). Scaling up pangolin conservation. *IUCN SSC, Pangolin Specialist Group Conservation Action Plan. Zoological Society of London, London, UK, 21pp*.

Challender, D., & Waterman, C. (2017). Implementation of CITES Decisions 17.239 B) and 17.240 on Pangolins (Manis spp.). *Prepared by IUCN for the CITES Secretariat. SC69 Doc*, *57*.

Challender, D. W. S., & Hywood, L. (2012). African pangolins under increased pressure from poaching and intercontinental trade. *Traffic Bulletin*, *24*(2), 53-55.

Challender, D. W., & MacMillan, D. C. (2014). Poaching is more than an enforcement problem. *Conservation Letters*, *7*(5), 484-494.

Clark, L., Van Thai, N., & Phuong, T. Q. (2008, June). A long way from home: the health status of Asian pangolins confiscated from the illegal wildlife trade in Viet Nam. In *Workshop on Trade and Conservation of Pangolins Native to South and Southeast Asia* (p. 111).

Corlett, R. T. (2007). The impact of hunting on the mammalian fauna of tropical Asian forests. *Biotropica*, *39*(3), 292-303.

Devineau, O., Shenk, T. M., Doherty Jr, P. F., White, G. C., & Kahn, R. H. (2011). Assessing release protocols for Canada lynx reintroduction in Colorado. *The Journal of Wildlife Management*, *75*(3), 623-630.

Douglas, L. R., & Alie, K. (2014). High-value natural resources: Linking wildlife conservation to international conflict, insecurity, and development concerns. *Biological Conservation*, *171*, 270-277.

Du Toit, Z., Grobler, J. P., Kotzé, A., Jansen, R., Brettschneider, H., & Dalton, D. L. (2014). The complete mitochondrial genome of Temminck's ground pangolin (Smutsia temminckii; Smuts, 1832) and phylogenetic position of the Pholidota (Weber, 1904). *Gene*, *551*(1), 49-54.

Eastridge, R., & Clark, J. D. (2001). Evaluation of 2 soft-release techniques to reintroduce black bears. *Wildlife Society Bulletin*, 1163-1174.

Engler, M., & Parry-Jones, R. (2007). Opportunity or threat: The role of the European Union in global wildlife trade.

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. Sage publications.

Gandiwa, E., Heitkönig, I. M., Lokhorst, A. M., Prins, H. H., & Leeuwis, C. (2013). Illegal hunting and law enforcement during a period of economic decline in Zimbabwe: A case study of northern Gonarezhou National Park and adjacent areas. *Journal for Nature Conservation*, *21*(3), 133-142.

Giangaspero, M., & Al Ghafri, M. K. S. (2014). Poaching: A Threat for Vulnerable Wild Animal Species in Oman. *Tropical Medicine & Surgery*.

Gomez, L., Leupen, B. T. C., & Hwa, T. K. (2016). The trade of African pangolins to Asia: a brief case study of pangolin shipments from Nigeria. *Traffic Bulletin*, *28*(1), 3-5.

Griffiths, R., Murn, C., & Clubb, R. (2010). Survivorship of rehabilitated juvenile Tawny Owls (Strix aluco) released without support food, a radio tracking study. *Avian Biology Research*, *3*(1), 1-6.

Haas, T. C., & Ferreira, S. M. (2015). Federated databases and actionable intelligence: using social network analysis to disrupt transnational wildlife trafficking criminal networks. *Security Informatics*, *4*(1), 2.

Heath, M. E, & Coulson, I. A. N. (1997a). Home range size and distribution in a wild population of Cape pangolins, Manis temminckii, in north-west Zimbabwe. *African Journal of Ecology*, *35*(2), 94-109.

Heath, M. E., & Coulson, I. M. (1997b). Preliminary studies on relocation of Cape pangolins Manis temminckii. *South African Journal of Wildlife Research-24-month delayed open access*, *27*(2), 51-56.

Heinrich, S., Koehncke, A., & Shepherd, C. R. (2019). The role of Germany in the illegal global pangolin trade. *Global Ecology and Conservation*, *20*, e00736.

Heinrich, S., Wittman, T. A., Ross, J. V., Shepherd, C. R., Challender, D. W. S., & Cassey, P. (2017). The global trafficking of pangolins: A comprehensive summary of seizures and trafficking routes from 2010–2015. *TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia*.

Hu, X. M., Wen, C. P., & Xie, Z. J. (2012). History and Application of Pangolin Scales. *Chinese Archives of Traditional Chinese Medicine*, *30*, 590-592.

IUCN, 2019. The IUCN Red List of Threatened Species. Version 2018-2, 17 January 2019. http://www.iucnredlist.org. Downloaded on 18 July 2019

Jacobsen, N. G., Newbery, R. E., De Wet, M. J., Viljoen, P. C., & Pietersen, E. (1991). A contribution of the ecology of the Steppe pangolin *Manis temminckii* in the Transvaal. *Zeitschrift für Säugetierkunde*, *56*(2), 94-100.

Kassambara, A., Kosinski, M., Biecek, P., & Fabian, S. (2017). Package 'survminer'. *Drawing Survival Curves using 'ggplot2'. (R package version 0.3. 1.)*.

Kleiman, D. G. (1989). Reintroduction of captive mammals for conservation. *BioScience*, *39*(3), 152-161.

Krigbaum, J. (2005). Reconstructing human subsistence in the West Mouth (Niah Cave, Sarawak) burial series using stable isotopes of carbon. *Asian Perspectives*, 73-89.

Laakso, L., Beukes, J. P., Van Zyl, P. G., Pienaar, J. J., Josipovic, M., Venter, A., ... & Tuovinen, J. P. (2013). Ozone concentrations and their potential impacts on vegetation in southern Africa. In *Developments in Environmental Science* (Vol. 13, pp. 429-450). Elsevier.

Medway, L. (1977). The Niah excavations and an assessment of the impact of early man on mammals in Borneo. *Asian Perspectives*, *20*(1), 51-69.

Merem, E. C., Twumasi, Y., Wesley, J., Isokpehi, P., Fageir, S., Crisler, M., ... & Nwagboso, E. (2018). Assessing the Menace of Illegal Wildlife Trade in the Sub Saharan African Region. *Advances in Life Sciences*, *8*(1), 1-23.

Mucina, L., Rutherford, M. C., & Powrie, L. W. (2006). Vegetation Atlas of South Africa, Lesotho and Swaziland. *The Vegetation of South Africa, Lesotho and Swaziland'.(Eds L. Mucina and MC Rutherford.) pp*, 748-789.

Nash, H. C., Wong, M. H., & Turvey, S. T. (2016). Using local ecological knowledge to determine status and threats of the Critically Endangered Chinese pangolin (*Manis pentadactyla*) in Hainan, China. *Biological Conservation*, *196*, 189-195.

NDPP. (2018). *Annual report 2017/2018*. Available from: https://www.npa.gov.za/sites/default/files/annual-reports/NDPP Annual Report- 2017-18.pdf

NISCWT. (2017). *National Integrated Strategy to Combat Wildlife Trafficking (NISCWT) Securing South Africa ' s Wildlife Heritage : Breaking the Illicit Value Chain of Wildlife Trafficking*. *February*. Availbable from: http://pmg-assets.s3-website-eu-west-1.amazonaws.com/170530NISCWT.pdf

NPA (2018). National Prosecuting Authority of South Africa, South African Government.

Parr, C. L. (2008). Dominant ants can control assemblage species richness in a South African savanna. *Journal of Animal Ecology*, *77*(6), 1191-1198.

Perera, P. K. P., Karawita, K. V. D. H. R., & Pabasara, M. G. T. (2017). Pangolins (*Manis crassicaudata*) in Sri Lanka: a review of current knowledge, threats and research priorities. *Journal of Tropical Forestry and Environment*, *7*(1).

Phelps, J., Biggs, D., & Webb, E. L. (2016). Tools and terms for understanding illegal wildlife trade. *Frontiers in Ecology and the Environment*, *14*(9), 479-489.

Pietersen, D., Jansen, R., Swart, J., & Kotze, A. (2016). A conservation assessment of *Smutsia temminckii*. *The red list of mammals of South Africa, Lesotho and Swaziland. South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust*.

Pietersen, D. W., Jansen, R., Swart, J., Panaino, W., Kotze, A., Rankin, P., & Nebe, B. (2020). Temminck's pangolin Smutsia temminckii (). In *Pangolins* (pp. 175-193). Academic Press.

Pietersen, D. W., McKechnie, A. E., & Jansen, R. (2014a). Home range, habitat selection and activity patterns of an arid-zone population of Temminck's ground pangolins, *Smutsia temminckii*. *African Zoology*, *49*(2), 265-276.

Pietersen, D. W., McKechnie, A. E., & Jansen, R. (2014b). A review of the anthropogenic threats faced by Temminck's ground pangolin, *Smutsia temminckii*, in southern Africa. *African Journal of Wildlife Research*, *44*(2), 167-178.

Piper, P. J., Rabett, R. J., & Cranbrook, E. O. (2007). New discoveries of an extinct giant pangolin (Manis cf. palaeojavanica Dubois) at Niah Cave, Sarawak, Borneo: biogeography, palaeoecology and taxonomic relationships. *Sarawak Museum Journal*, *84*, 207-226

Rosen, G. E., & Smith, K. F. (2010). Summarizing the evidence on the international trade in illegal wildlife. *EcoHealth*, *7*(1), 24-32.

Rutherford, M. C., Mucina, L., Lötter, M. C., Bredenkamp, G. J., Smit, J. H. L., Scott-Shaw, C. R., Hoare, D. B., Goodman, P. S., Bezuidenhout, H., Scott, L., Ellis, F., Powrie, L., Siebert, F., Mostert, T. H., Henning, B. J., Ventner, C. E., Camp, K. G. T., Siebert, S., Matthews, W. S., & Hurter, P. (2006). Savanna Biome. In *The Vegetation of South Africa, Lesotho and Swaziland* (pp. 440–529).

Rutherford, M. C., & Powrie, L. W. (2006). Biomes and bioregions of southern Africa . In : Mucina , L ., Rutherford , M . C . (Eds .), The vegetation of South Africa , Lesotho and Swaziland. *Strelitzia* ., *19 (2006)*(January 2016), 31–51

Sacerdote-Velat, A. B., Earnhardt, J. M., Mulkerin, D., Boehm, D., & Glowacki, G. (2014). Evaluation of headstarting and release techniques for population augmentation and reintroduction of the smooth green snake. *Animal Conservation*, *17*, 65-73.

Shepherd, C. R., Connelly, E., Hywood, L., & Cassey, P. (2017). Taking a stand against illegal wildlife trade: the Zimbabwean approach to pangolin conservation. *Oryx*, *51*(2), 280-285.

Sun, N. C. M., Arora, B., Lin, J. S., Lin, W. C., Chi, M. J., Chen, C. C., & Pei, C. J. C. (2019). Mortality and morbidity in wild Taiwanese pangolin (*Manis pentadactyla pentadactyla*). *PloS one*, *14*(2).

Swanepoel, L. H., Somers, M. J., Van Hoven, W., Schiess-Meier, M., Owen, C., Snyman, A., ... & Dalerum, F. (2015). Survival rates and causes of mortality of leopards *Panthera pardus* in southern Africa. *Oryx*, *49*(4), 595-603.

Swart, J. M., Richardson, P. R. K., & Ferguson, J. W. H. (1999). Ecological factors affecting the feeding behaviour of pangolins (*Manis temminckii*). *Journal of Zoology*, *247*(3), 281-292.

Symes, W. S., McGrath, F. L., Rao, M., & Carrasco, L. R. (2018). The gravity of wildlife trade. *Biological Conservation*, *218*, 268-276.

Therneau, T. M., & Lumley, T. (2014). Package 'survival'. *Survival analysis Published on CRAN*, *2*, 3.

UK Government. (2014). Declaration: London Conference on the Illegal Wildlife Trade. *London Conference on the Illegal Wildlife Trade*, 12. Available from: https://cites.org/sites/default/files/eng/news/sundry/2014/london-wildlife-conference-declaration-140213.pdf.

Vijayan, M., Yeong, C., & Ling, D. (2009, June). Captive management of Malayan pangolins *Manis javanica* in the Night Safari. In *Workshop on trade and conservation of pangolins native to south and southeast Asia* (p. 119).

Wang, B., Yang, W., Sherman, V. R., & Meyers, M. A. (2016). Pangolin armor: overlapping, structure, and mechanical properties of the keratinous scales. *Acta biomaterialia*, *41*, 60-74.

Warchol, G. L. (2004). The transnational illegal wildlife trade. *Criminal justice studies*, *17*(1), 57-73.

Warnes, G. R., Bolker, B., Lumley, T., Warnes, M. G. R., & Imports, M. A. S. S. (2018). Package 'gmodels'.

Wicker, L. V., Lourens, K., & Hai, L. K. (2020). Veterinary health of pangolins. In *Pangolins* (pp. 461-493). Academic Press.

Wickham, H., Chang, W., & Wickham, M. H. (2016). Package 'ggplot2'. *Create Elegant Data Visualisations Using the Grammar of Graphics. Version*, *2*(1), 1-189.

Willcox, D., Nash, H. C., Trageser, S., Kim, H. J., Hywood, L., Connelly, E., ... & Challender, D. W. (2019). Evaluating methods for detecting and monitoring pangolin populations (Pholidota: Manidae). *Global ecology and conservation*, e00539.

Wright, N., & Jimerson, J. (2020). The rescue, rehabilitation and release of pangolins. In *Pangolins* (pp. 495-504). Academic Press.

Zhou, Z. M., Zhou, Y., Newman, C., & Macdonald, D. W. (2014). Scaling up pangolin protection in China. *Frontiers in Ecology and the Environment*, *12*(2), 97-98.