The Pangolin Universal Notching System (PUNS): A Foundational Scale Marking Methodology for Pangolins

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Abstract

Despite thousands of individuals entering the illegal wildlife trade each year, pangolin population status assessments are largely nonexistent, particularly in areas with high exploitation and limited field assets. Pangolins have a unique body structure, as they are covered in keratin-based scales. Currently, there is no universal scale marking methodology available for pangolins [despite nearly half of] pangolin programmes utilising marking for reference and cataloguing. Each programme establishes and manages its own systems, leading to inconsistencies, as well as limited data sharing.

To facilitate pangolin population monitoring and biological research, we developed a standardised method for assigning individual identification numbers called the Pangolin Universal Notching System (PUNS). The PUNS is neither resource- nor training-intensive, factors which can facilitate successful adoption and implementation globally. Its application can help address knowledge gaps in the areas of pangolin ageing, reproduction, survivorship, migration, and local trafficking patterns and can be used in combination with other tagging techniques to better understand pangolin biology.

Keywords: *Pangolin, Scale Marking, Tracking, Wildlife Conservation, Endangered Species, Smutsia, Phataginus, Manis*

Introduction

Conventional and highly accessible animal marking systems such as dyeing bird feathers (Bendell & Fowle, 1950; Paullin & Kridler, 1988), painting mammal skin and fur (Pienaar, 1970; Walker 2012), ear notching hoofstock (Blair, 1941), or removing tissue, scale, or scute pieces, in amphibians and reptiles (Cagle, 1939; Turner, 1960; Jennings et al., 1991; Ferner, 2007) have been widely used to identify individuals of many species over variable lengths of time. These simple notching or marking systems date back to the early 20th century when Cagle (1939) described a simple scute-notching system in hard-shelled turtles where scutes were assigned a number and then notched with a file or scissors. Permanently identifying individuals in longitudinal studies in a way that does not disrupt their natural behaviours has proven to be instrumental to the study of growth and ageing, reproduction, survivorship, and migration patterns (Cagle, 1939; Plummer & Ferner 2012). Though this foundational system has been adapted to a variety of species or project needs (Bury et al., 2012; CPS, 2023; Ernst et al., 1974; Holland 1994; Plummer & Ferner 2012; Nagle et al., 2017), these areas of basic biological understanding remain knowledge gaps in essentially all pangolin species (Willcox et al., 2019; Heighton, S. P., & Gaubert, P., 2020).

There are eight extant species of pangolin, four of which are native to Africa: Temminck's pangolin (*Smutsia temminckii*), giant ground pangolin (*S. gigantea*), black-bellied pangolin (*Phataginus tetradactyla*), and white-bellied pangolin (*P. tricuspis*) and four of which are native to Asia: Chinese pangolin (*Manis pentadactyla*), Indian pangolin (*M. crassicaudata*), Philippine pangolin (*M. culionensis*), and Sunda pangolin (*M. javanica*) (Challender et al., 2019; Gaubert et al., 2020; IUCN, 2024). All eight species of pangolin have decreasing populations according to the IUCN (2024), and are listed on Appendix I of the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora, which is the highest level of international protection against trafficking that a species may be granted (Challender & O'Criodain, 2020). Pangolins, their name being derived from the Malay word "peng-goling" which means "ones that roll up," (Kingdon, 1977) are unique species with distinct morphology and behaviour. They have been referred to as walking pinecones, scaly anteaters, and even perambulating artichokes due to their long tongues, absence of teeth, unique keratin-based scale 'armour' used for protection and diet primarily consisting of ants and termites (Wang et al., 2016). They live primarily in burrows, are known to dig, climb, walk, and swim throughout their native habitats and-when threatened-curl into a defensive ball, allowing their scales to serve as their primary source of protection (Kingdon, 1977; Vickaryous & Hall, 2006). Pangolins vary widely in size with the smallest species, the white-bellied pangolin, measuring 1-3 kg and 100 cm long (Jansen et al., 2020) and the largest species, the giant pangolin, measuring over 30 kg and 140-180 cm long (Hoffman et al., 2020).

Virtually no population of any pangolin species has been completely quantitatively assessed. This limits the ability to understand impacts of natural and anthropogenic pressures, particularly in areas where there is high exploitation, and/or field assets are limited – as is the case for most species in most range countries. While the vast majority of pangolin trafficking is centred on scales, it is not uncommon for live animals to be intercepted (Shepherd et al., 2017; Challenger et al., 2020; Bashyal et al., 2021) and need rehabilitation prior to release. Further, while possible, (Gaubert et al, 2016; Zhang et al., 2020; Ewart et al., 2021; Tinsman et al., 2023) there is limited access to the genetic methods needed to recover information about individuals (live, carcasses, or scales) intercepted during trafficking. Effective methods of monitoring and tracking pangolins are essential to understanding the extent of population declines and, hopefully, recovery following intervention.

Currently, efforts are under way to address these needs. One approach involves attaching battery-powered tracking devices, such as very high frequency (VHF), satellite (SAT), and global positioning system (GPS) tags. While all devices have been utilised, VHF tags are most common due to their cost-effectiveness, long battery life, light weight, and capability to gather precise location data through triangulation (Willcox et al., 2019; Morin et al., 2020). Nevertheless, the signal may fluctuate in adverse weather conditions, and relocating individuals can be labour-intensive, often necessitating the use of ground vehicles, aircraft, or drones to attain proximity to the signal or overcome geographical obstacles (Saunders et al., 2022). Additionally, tagged individuals face the risk of straying beyond the study area or venturing onto private properties where practitioners do not have authorisation from landowners to enter. Moreover, since many pangolin species inhabit underground burrows, signal range may be significantly restricted during daylight hours when tracking tagged individuals is safest for technicians (Pagès, 1975). Given these limitations, supplementing tracking devices with a sustainable low- to no-technology based identification system would be a benefit to long-term pangolin tracking efforts.

One key non-invasive method of identifying and tracking live individuals currently in use for a multitude of species (e.g., hoofstock (Blair, 1941), amphibians and reptiles (Ferner, 2008), and marine mammals (Walker et al., 2012)) is notching or marking. This entails using a tool-such as a drill, punch, or file- to remove a portion of tissue, scales, or scutes in order to permanently identify the individual. When used in tandem with advanced technologies such as telemetry, notching systems are known to often persist after these technologies fail, are lost or damaged, batteries die, or reach their functional endpoint.

There is no universal scale marking methodology available to pangolin tracking practitioners at present (Willcox et al., 2019; Morin et al., 2020). While pangolin scales vary in size across species, they all exhibit similar structural and mechanical properties (Wang et al., 2016) enabling them to withstand the force and pressures of drilling. Half of pangolin tracking programmes surveyed already use some method to notch the scales across four different species of pangolin: Sunda pangolin, Black-bellied pangolin, White-bellied pangolin, and Temminck's pangolin (Ruden et al., 2024). Currently, each programme creates and manages its own notching system. This creates inconsistencies across programmes and a lack of uniformity in research across the global pangolin conservation community, potentially impeding data sharing. Our team is poised to meet this moment through the creation and implementation of a universal marking code.

Here we develop and propose the Pangolin Universal Notching System (PUNS). We created the PUNS to address the lack of a uniform protocol and streamline efforts already underway within the pangolin community. The PUNS combines elements of existing systems in a way that accommodates both the unique morphology and behaviours of pangolins. While current programmes are encountering only small numbers of pangolins, The PUNS is designed to accommodate large volumes in order to address cumulative totals over extended periods of time for individual programmes or possible integration with a central data repository. Importantly, the PUNS is applicable to a broad audience from trained researchers to nontechnical staff, including law enforcement.

Methods:

We conducted both a literature review and practitioner survey assessing current tracking methods utilised across the pangolin research community from January to September 2023. (Ruden, et al. 2024). Despite no formal mention in the literature, eight of 15 respondents (53%) described marking or notching pangolin scales for identification utilising their own ad hoc secondary marking systems on four different species of pangolin, with seven of those programmes acquiring pangolins from wildlife trafficking and trade. Four of these systems already involved drilling a series of holes in the scales, and two additional systems drilled through scales to attach numbered cattle ear tags. Other systems included one practitioner utilising a tattoo drill and one using paints (Table 1).

Further discussions with practitioners led to our decision to create a pangolin-specific notching code that could be used to mark individuals long-term and to complement other tracking methodologies. During these discussions, considerations like interspecific variation in body size, interspecific and anatomical diversity in scale morphology, life histories (e.g., presence of dependent young, primary habitat), and prior experiences altering scales were considered. Following meetings with respondents, we also reached out to the creator of the North American code for hard-shelled turtles (Nagle et al., 2017), to discuss developing a similar code for pangolins and gain additional insight regarding best practises.

Results:

A numerical based code to accommodate a growing catalogue of individuals over the long term, that also possessed the ability to rapidly assess sex, was selected. It was determined that drilling a centrally located area, proportional to scale size, would be best to minimise likelihood of scale breakage. The PUNS system (Figure 1a) was created by adapting and combining existing hard-shell turtle (Nagle et al., 2017) and hoofstock (Blair, 1941) marking methodologies. The PUNS uses a numerical based code to communicate individual identification and/or sex through a series of notches involving scales on or adjacent to the dorsal midline.

In the PUNS, codes are assigned and read viewing the pangolin on its stomach with the head facing away from and the tail toward the observer (Figure 1a). The first scale immediately left of the midline scale row at the pectoral girdle (shoulder) and the first scale immediately right of the midline scale row at the pectoral girdle are always labelled 1 and 100, respectively. The pectoral girdles and the scapula (shoulder blade) can be palpated beneath the scales to identify the starting location. This location can also be identified by locating the change in scale morphology that delineates the smaller, thinner, head-and-neck scales from the thicker, wider trunk scales (Challender, D. et al., 2019). Once the starting point is identified, the first eight scales on each side of the midline row are numbered. Moving toward the tail from the starting location on the left side, scales are numbered 1, 2, 4, 7, 10, 20, 40, and 70. Moving toward the tail from the starting location on the right side scales are numbered 100, 200, 400, 700, 1000, 2000, 4000, and 7000. Scale numbers are marked cumulatively to attain the number required. The midline scale row is used to indicate the individual’s sex. The first scale in the midline, between scales numbered 1 and 100, is marked for males. The fifth scale, between scales numbered 10 and 1000, is marked for females. For example, to assign a male pangolin the unique identification code 7238, practitioners would mark the 7000, 200, 20, 10, 7, and 1 scales as well as the first scale along the midline indicating male (Figure 1b). This system provides for a total of 15,554 uniquely marked individuals.

Once the individual pangolin code has been assigned, the necessary scales should be cleaned of debris and marked with a wax pencil or marker. A hard barrier should be gently placed between that scale and any underlying scales or soft tissue for protection. Using a standard drill and a bit no greater than ⅓ the total width of the narrowest part of the scale, one hole will be drilled per scale. Marks should be placed centrally in the exposed portion of the scale and drilled straight through the scale leaving a circular hole. Covering the pangolin's eyes with a cloth or small towel to minimise stress is also recommended. Should the pangolin curl into a defensive position, marking should be completed while curled rather than forcing the animal to straighten. This may also allow for greater separation and access to targeted scales. If the scale meant for marking is obscured by the tail while in the defensive position, the tail should be moved out of the way gently, if possible, or marking could be finished at a later time.

Pangolin tracking practitioners are already notching pangolins of all size ranges and scale thicknesses, including the two smallest species. Further, the PUNS code is designed to ensure this notching is standardised and applied to the region of the body with the largest scales. As a result, we were confident in the ability of the code to be effectively utilised in all species without extensive pre-testing.

Discussion

Establishing a universal scale marking system for pangolins will be helpful to facilitate the consistent gathering and sharing of conservation data globally. Since there are substantial voids in understanding pangolin populations, moving forward with a uniform system will help leverage current and future efforts for optimised data integration. Overall, this proposed system seeks to establish a standardised, accessible, and broadly applicable notching protocol that could be implemented globally with minimal resources and training utilising techniques the pangolin tracking community is already using and familiar with.

As evidenced by notching already being successfully used by pangolin tracking practitioners across a breadth of species, including the smallest species, the PUNS is adaptable to all eight species of pangolin, regardless of total scale number or scale morphology. The PUNS is intended for use on individuals in good health and body condition that are not obviously pregnant, lactating, or young enough to be nursing. This ensures that individuals are large enough for notching, scales are of adequate thickness, and stress would not lead to any interference in the mother-pup relationship. Given the potential volume of pangolins encountered long-term through trade recovery, rehabilitation, and *in situ* research, the PUNS numerical coding system allows a significant number (maximum of 15,554) to be notched and available for longitudinal studies.

Due to high scale count variability among pangolin species (Cota-Larson, 2017; Ullmann et al., 2019), it was important to have a specific anatomical landmark for the starting point to ensure uniformity in notching execution. All species have at least eight scales in the first lateral row, and by using the first eight scales on each side, researchers can easily remember that all numbers below 100 are on the left and above 100 are on the right. The area posterior to the pelvic girdle (hips) was avoided to eliminate confusion from drill holes made during traditional transmitter placement (Pagès, 1975; Lim T-Lon, 2008; CPCP, 2014; Pietersen et al., 2014; Schoppe, 2015; Sun et al., 2019).

In addition to being highly accessible to practitioners with limited resources or training constraints, a significant advantage of the PUNS is the simplicity of the code which makes it easily adapted for individual programme needs and goals. Programmes could assign subsets of their codes to different geographic regions or specific projects to rapidly provide additional detail about where the individual was originally encountered. Notch adornments could also be used to increase visibility to researchers in the field or by camera trap. These adornments could include: Beaded wires or reflective paints similar to what is used in iguanids (Rodda et al., 1988), cattle ear tags, coloured bird leg bands (Silvy et al., 2012), or any other materials that could be used as visual cues. It is important to note, however, that ear tags and bands used in other species have been associated with short term rubbing, discomfort, and are known to rip or fall out. (Johnston & Edwards, 1996; Griesser et al., 2012)). While adorning a notched scale will be different in pangolins as soft tissue is not involved, there could still be unexpected impacts. Therefore, given pangolins' propensity for being found in dense foliage and burrows, any adornment techniques considered should be evaluated by each programme to ensure animal safety is not compromised through increased predation, poaching, or entanglement risks.

As a foundational system, the PUNS will not–nor is it intended to be–a panacea that is appropriate to apply in every circumstance and there are limitations to its execution. First, the animal must be healthy enough to be handled long enough to be marked, either in the wild or in a post-rehabilitation setting. While the time needed to drill the holes is less than what would be needed to attach a telemetry tag/tracking device, animal health and stress would still need to be taken into consideration. Second, if an animal were to lose or damage a marked scale over the course of its lifetime, only a partial code would be able to be identified when recaptured. Therefore, unlike in hard-shelled turtles, or tattooing in certain mammals, notching in pangolins may be vulnerable to some uncertainty with scale wear. Third, if an individual marked with a customised code was intercepted by another programme or from trafficking, programme-specific adaptations, such as using region or project-specific codes, that detailed information may not be immediately known. However, in this circumstance, the code for that pangolin could still be identified and traced as long as those recovering the pangolin were trained in interpreting the PUNS system. Finally, this code works best if the pangolin is in hand while reading the code. While the marked code could be read from a short distance, or possibly from a burrow camera trap photo, this notching system does not facilitate visibility across long distances. It may also be challenging to read if the pangolin is viewed unilaterally, a pup is attached, or mud or other debris are caked into the holes obstructing the view. Notwithstanding these limitations, the PUNS system signifies a notable advancement in pangolin conservation endeavours. Its inherent simplicity and adaptability render it a valuable asset, providing a non-intrusive method for the identification and tracking of individuals. The PUNS system holds promise for enhancing our understanding and protection of these endangered creatures.

Code management and organisation could be completed at the project, regional, national, or international levels. We strongly recommend that pangolin practitioners work with the IUCN SSC Pangolin Specialist Group to identify an organisation or organisations to develop, house, and manage a centralised database system to serve as the primary communication tool and allow for increased data sharing ability. Given the distribution of pangolins in multiple countries, their status as the most trafficked mammal in the world (Aisher, 2016), and the reality that a live trafficked animal may be intercepted and rehabilitated far from where it was originally marked, (Wright & Jimerson, 2020) the ability to easily share data in this way will be instrumental to conservation efforts. This system could be modelled after existing species tag data-sharing systems and their respective organisation types (i.e. non-profit, private business, academia, governmental), such as: the Sea Turtle Tag Inventory managed by the Archie Carr Center for Sea Turtle Research (ACCSTR) at the University of Florida (ACCSTR, 2023) and the TagFinder programme through Seaturtle.org (SeaTurtle.org, 2023), the thoroughbred horse Interactive Registration™ Tattoo Lookup and Tattoo Research programmes managed by the Jockey Club (The Jockey Club, 2023), the Monarch Tagging programme managed by Monarch Watch (Monarch Watch, 2023), or the Bird Banding Laboratory managed by the United States Geological Survey (USGS) (USGS, 2023).

In summary, the PUNS is a standardised, accessible, and customisable system for marking pangolin species that does not currently exist within the pangolin conservation community despite programmes regularly notching pangolins. It is neither resource- nor training- intensive, which facilitates its accessibility and implementation globally. If implemented, it could aid in addressing knowledge gaps in the areas of pangolin ageing, reproduction, survivorship, migration, and local trafficking patterns through longitudinal study data, especially when paired with other tracking types and technologies.

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Conflicts of interest None

Ethical standards This research needed no special permissions and abided by all *Oryx* guidelines on ethical standards.

Data availability Data that support this study are available from the corresponding author, JMM, upon reasonable request.

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Species	Ad hoc Method	Number of programmes using method	Pangolin acquisition methods
Sunda pangolin *Manis javanica*	Cattle ear tags attached to scales	1	Trafficking/trade
Temminck's pangolin *Smutsia temminckii*	Hole drilling	3	Trafficking/trade & Wild caught
	Cattle ear tags attached to scales	1	
White-bellied pangolin *Phataginus tricuspis*	Hole Drilling	1	Trafficking/trade & Wild caught
	Tattoo drilling	1	
	Scale Painting	1	
Black-bellied pangolin *Phataginus tetradactyla*	Hole Drilling	1	Wild caught

Table 1: Ad hoc tracking methods by species and pangolin acquisition type: Eight pangolin conservation programmes are using ad hoc marking as a supplemental tracking technique across four pangolin species, which were obtained through trafficking/trade or by being wild caught specifically for research efforts. Several programmes are working across multiple species.

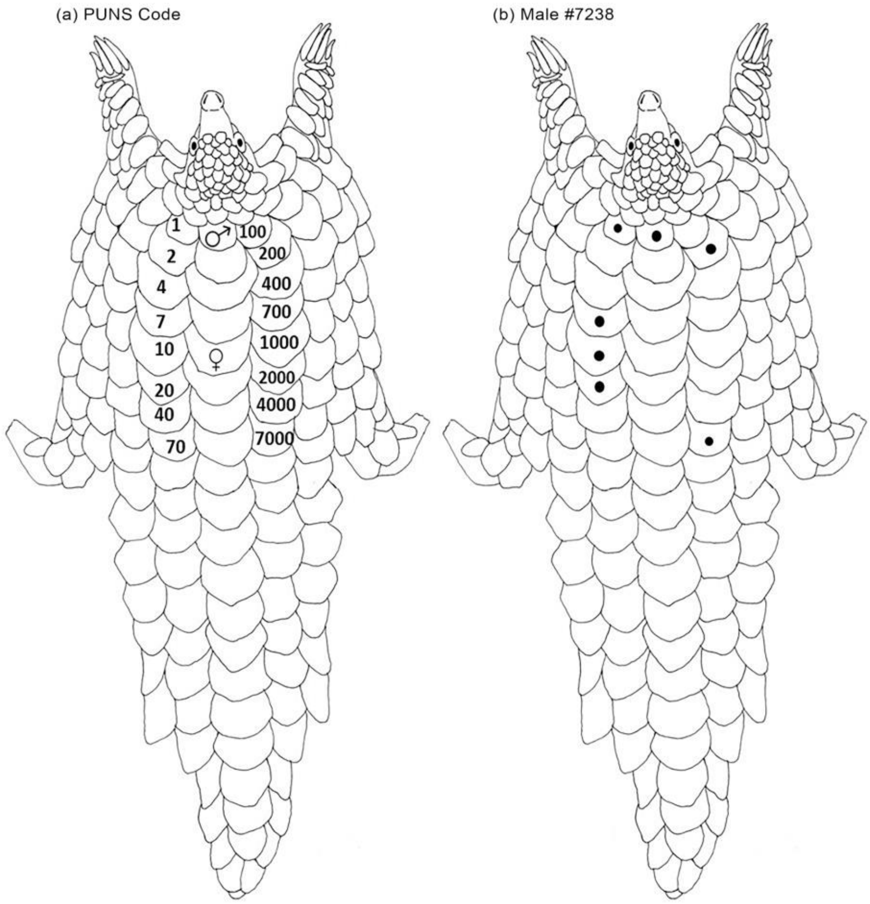

Figure: 1: Pangolin Universal Notching System (PUNS) applied to a Temminck's pangolin (*Smutsia temminckii*). (a) Dorsal view: On its stomach with the anterior (head) at the top of the image with the pangolin facing away from the observer. The first scale immediately left of the midline scale row at the pectoral girdle (shoulder) and the first scale immediately right of the midline scale row at the pectoral girdle are always 1 and 100, respectively. The first midline row scale between the 1 and 100 scales is male, and the fifth midline row scale is female. (b) Male Individual #7238 marked with the Pangolin Universal Notching System (PUNS): To identify number 7238, the 7000, 200, 20, 10, 7, and 1 scales as well as and the first scale in the midline, indicating male, are marked.