Utilizing Innovative Humanitarian animal-training solutions to tackle illegal wildlife trafficking

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Abstract

APOPO started with a simple question: could rats sniff out landmines and other explosives? With landmines posing serious threats to communities and traditional demining operations proving costly and inefficient, this once-unconventional idea offered a new approach. Now, after 30 years of successful demining and expanding the use of rats' olfactory capabilities for tuberculosis detection, APOPO has extended its work against the illegal wildlife trade, a complex transnational problem with serious consequences for biodiversity.

APOPO's scientific proof of principle in 2024 on wildlife detection rats proved that they are capable of detecting wildlife products like elephant ivory, pangolin scales, among other elements in controlled environments, and have transitioned to training on real scenarios, where they have reached an average precision of 83% and less than 15% incorrect detections. Now, two years later, APOPO has continued to improve the training and performance of the rats. (1)

For pangolin conservation, scent-detection rats could increase the interception of scales concealed in cargo at ports, the points where trafficked products leave source regions, and each seizure generates evidence that can help trace where the scales came from.

Discussion

Pangolins (family Manidae), the scale-covered, ant- and termite-eating mammals of Africa and Asia, are highly elusive and difficult to conserve because of their nocturnal and solitary habits. Yet their elusiveness has not prevented them from becoming one of the world's most heavily trafficked animals (2). Every five minutes, a pangolin is poached from the wild (3), and over the past decade, more than 553,042 pangolins were poached in the Illegal Wildlife Trade (IWT) across 49 countries (4).

All pangolin species are threatened (5) because their scales, meat, and bones are used in different countries, contributing to their decline (6). Data from 2024 show that global seizures declined by 84%, a trend linked to pandemic-related disruptions and enforcement efforts (7). This apparent

progress must be interpreted with caution, since seizures account for only 10% of trafficked shipments (8), suggesting the true scale of the trade is much larger. This detection gap is more evident in container trade, where approximately 2% of shipping containers are inspected by authorities (UNODC), and current screening tools, such as detection dogs, X-ray scanners, and smart sensors, are costly and time-consuming. Improving detection along trade routes therefore remains essential for pangolin conservation.

This review (i) summarizes pangolin biology and conservation status, (ii) examines the drivers and the structure of the pangolin trade, (iii) outlines current conservation approaches, and (iv) evaluates the potential of APOPO's scent-detection rats (wildlife detection rats), with a preliminary assessment of priority sites like Hong Kong or Cambodia.

The pangolin family and its conservation status

There are eight recognized species of Pangolins spanning 3 genera: *Manis*, *Smutsia*, and *Phataginus*. Four species are native to Asia, including the Sunda pangolin (*Manis javanica*), Chinese pangolin (*Manis pentadactyla*), Philippine pangolin (*Manis culionensis*), and Indian pangolin (*Manis crassicaudata*). The four species native to Africa are the Temminck's Pangolin (*Smutsia temminckii*), the Giant Ground Pangolin (*Smutsia gigantea*), the White-bellied Pangolin (*Phataginus tricuspis*), and the Black-bellied Pangolin (*Phataginus tetradactyla*;5). Genomic analysis of confiscated scales has also revealed a cryptic lineage, tentatively named *Manis mysteria* (9), and the Himalayan pangolin (*M. aurita*) has recently been revalidated as a distinct species (10). However, neither is yet formally recognized by the IUCN SSC Pangolin Specialist Group, highlighting how incomplete pangolin taxonomy remains.

Pangolins possess several distinct morphological traits; the most notable is the armor of keratinous scales, complemented by an array of adaptations suited to their insect-based diet of ants and termites (11), including their elongated snout and long tongue (12). Pangolins play a role in balancing insect populations in their ecosystem, with a single adult consuming over 70 million ants and termites annually (11), and burrowing by ground-dwelling species promotes soil aeration and the turnover of organic matter (13).

Pangolin species are arboreal or fossorial (5), with their habits adding to their elusiveness. As part of their behavior, pangolins curl into a tight ball when threatened (14); their common name "pangolin" is derived from the Malay word *pengguling*, meaning "one that rolls up" (14). While this defensive strategy is effective against natural predators, it leaves pangolins significantly vulnerable to poaching.

This vulnerability is reflected in their conservation status on the IUCN Red List; all eight recognized species are listed as Vulnerable, Endangered, or Critically Endangered (5). In the particular case of the Chinese pangolin, populations are estimated to have declined by more than

90% between the 1960s and the early 2000s, and the species has been considered commercially extinct since the mid-1990s (5). As Asian populations collapsed, demand shifted to Southeast Asian and then to African species, particularly the white-bellied pangolin (5), the most frequently encountered (15). Although no robust population estimate exists for this species, it is thought to have declined by about 40% over the past two decades, and the remaining species likewise face overexploitation and habitat loss (5).

Pangolin use across continents

The consumption of pangolins dates back more than 5,000 years, with pangolin scales (*Squama Manitis*) first appearing in *Bencao jing jizhu* (16), a landmark Chinese pharmaceutical text. Pangolin scales are mostly composed of alpha-keratin, a fibrous protein consisting of long polypeptide chains coiled up into a tight helical configuration. Studies have shown that this protein found in pangolin scales is chemically identical to that in human fingernails, containing no peptides or biologically active compounds that are specifically found only in pangolin scales (17). Despite this lack of scientific evidence supporting the alleged curative properties, a study by the non-profit organization WildAid finds that 70% of Chinese citizens believe pangolins have medicinal value (7). In Traditional Chinese Medicine (TCM), pangolin scales are believed to have effects such as curing rheumatism (7), promoting lactation, and reducing swelling (18). This expansion of claimed medicinal benefits, alongside legal mechanisms that enabled the selling, drove pangolin populations in China to the brink. It was not until 2025 that the Chinese government fully removed both raw pangolin scales and all formulas containing them, such as *Guilingji,* a formula believed to combat aging and male sexual dysfunction from *the Pharmacopeia of the People's Republic of Chin*a, an official list of approved ingredients in TCM (19). This decision followed years of criticism with the continued inclusion of pangolin- derived products and the accumulation of pangolin deaths.

Among these countries, West and Central Africa have become key supply hubs, shifting to Nigeria and the Democratic Republic of Congo (420), with Nigeria historically serving as the largest-volume transit country (20, 15, 7). China remains the top destination, followed by Vietnam and Laos (20). Pangolins are particularly sought after for their scales, as well as their meat and bones, which are prized for their healing properties in traditional medicine across China, Vietnam, and parts of Africa (6). Challenges in pangolin conservation are deeply intertwined with the growing IWT. Data on their population status, behavior, and life history remain largely scarce and unknown (21), making it difficult for conservationists to detect these creatures and identify poachers targeting them, even as their populations decline. Attributed to pandemic-related disruptions and enforcement efforts, this apparent progress should be interpreted with caution (7), as seizure data are estimated to capture as little as 10% of actual trading shipments (8), suggesting that the true scale of trafficking may remain higher than

suggested. Therefore, the key issue remains in the detection and dismantling of these IWT groups to support pangolin conservation.

Patterns of pangolin consumption differ across regions. In Africa, pangolin poaching has historically been more closely tied to subsistence bushmeat needs and localized cultural, spiritual, and medicinal practices than exclusively to commercial food markets (22). In Traditional African Medicine, pangolin scales are believed to be used for medicinal and spiritual purposes, such as protection against bad omens and to bring good luck (21). Specific communities, such as the Awori people native to southwestern Nigeria, use more than just their scales in their medicine, using their bones and eyes, which are believed to have healing powers (21).

Pangolin consumption is considered a status symbol for many, with a Guangzhou businessman stating that “Pangolin hotpot is considered a novelty treat, a gesture of hospitality” (21). With its high price and rarity, pangolin meat has often become appealing to the elite as a way to flaunt their social position (21). Pangolin skins are also processed into leather and used to make luxury goods, including handbags, footwear, and belts, while their scales and claws are used as decorations (22). High market demand has driven prices in China up tenfold over the past decade (23).

Figure 1. A coat of armor made of pangolin scales (Soewu et al.) (23)

For a trade that involves minimal production cost beyond capture, the illegal trade of pangolins offers substantial financial incentives for poachers (19). Unlike poaching other wildlife species, pangolin hunting requires little skill, training, or the need for specialized equipment (19, 20). In poaching, snare traps are most commonly used, with production costs ranging from 100.00 Nigerian Naira (NGN) to 200.00 NGN, translating to approximately $0.073 USD (22). In contrast, the pangolin has a market value of 400.00 United States Dollars (USD) per kilogram of scales, as approximated in 2023, with advertised retail prices ranging from 190.00 USD to 1020.00 USD per kilogram (24). With 1 kg of scales equating to 1 kg, depending on the species, a common estimate is that 1 kg of scales is equivalent to 3 pangolins, representing the deaths of multiple animals for every kilogram traded (25). This disparity between low capture costs and high market value has perpetuated the global IWT of Pangolins moving across borders.

A History of the IWT

The Illegal Wildlife Trade is the fourth most lucrative criminal trade in the world, generating an estimated $20 billion USD in illicit revenue yearly, growing at nearly three times the pace of the global economy (26). It is a component of Environmental Crimes, as defined by UNEP and INTERPOL, which are illegal activities that harm the environment and exploit natural resources for the benefit of individuals, groups, or companies (26). Specifically, the IWT refers to activities including the “illegal capture, collection, killing, or harvesting (poaching) of wildlife (animals and plants), the illegal transport (smuggling) of wildlife (domestically or across international boundaries), and all trade-related activities such as illegal selling, buying, receiving, or giving of wildlife or their products” (27). As a wildlife product moves from its point of harvest to households, it passes through multiple actors that harvest, facilitate, and manage the network. While the type and time taken through these pathways vary depending on the location or type of animal product, the general timeline follows a supplier-intermediary-consumer trade chain framework.

Pangolin Trafficking: An Overview

Pangolin trafficking operates through a complex transnational supply chain that links poaching hotspots in Africa and Asia to global consumer markets. Poachers harvest pangolins from source countries, particularly across West and Central Africa, before local intermediaries purchase, aggregate, and transport scales or carcasses to export hubs. These export hubs then distribute pangolins and their products to large consumer markets in East and Southeast Asia (20).

Pangolin trafficking begins with the direct poaching or hunting of wildlife taking place in source communities (e.g., Nigeria). Local poachers are classified as local or non-local specialists, depending on the location where poaching takes place (28). Poachers use a combination of manual tracking and snare traps to capture live pangolins. Pangolins are poached mainly at night with a mixture of manual tracking (56%) and traps (40%), with the latter including manual capture (69%), clubs (23%), and guns (8%) (23). Poaching groups averaged three people, accompanied by two to four dogs, and occurred year-round, mainly in the dry months (28).

Figure 2. c) Traditional Snare Trap d) White-bellied pangolin caught in a traditional trap in Mpem et Djim National Park, Cameroon (Simo et al.) (29)

Intermediaries, namely logisticians who operate actively by regularly visiting villages and communities and asking for poacher contacts, then approach these poachers to supply live pangolins. "*There are no minimum quotas, even one will be delivered direct to the buyer*", respondents in Archer et al. (2021)'s study report. Transactions happen as few as one pangolin, and the transfer of the pangolin from the poacher to the intermediary as soon as possible to reduce the risk of being caught (28). Depending on the situation, the descaling and killing of pangolins are carried out by poachers or intermediary logisticians (29). Once dead, pangolins are immersed in hot water or fire where they are thus descaled; the scales are thus dried for sale (20). While small quantities of leftover meat may rarely enter local bushmeat markets, pangolin meat is not a typical food –it remains largely available to the elites due to its scarcity (30). The intermediary logistics workers then work with other facilitators to conceal, document, and transport these pangolins to specialist smugglers once they have collected a certain amount (e.g., 500 kilos of whole pangolins). Specialist smugglers handle much larger volumes of pangolins in warehouses within the area before arranging shipment to destination countries (28).

Figure 3. a) Pangolin live in captivity b) Pangolin, processed (Soewu et al.) (22)

Specialist smugglers are often those with enough wealth and connections, namely wealthy business owners, high-level government officials, or foreign workers who often have ties with organized criminal networks. They smuggle pangolin scales by sea, air freight, and land routes, concealed under or among frozen meat, ice, cashew nuts, or hidden in logs using candle wax (20, 31). These large consignments of pangolin products are misdeclared or concealed by smugglers who bribe corrupt Government officials, specifically those working in customs departments at airports and seaports (31). Bribes also go to pilots, boat operators, and enforcement personnel, while bonuses were provided if shipments were successful (28). These well-structured and sophisticated operations operate across borders, violating environmental regulations and criminal laws, including customs fraud and money laundering (31). A study by Archer et al. (2021) reports traffickers intentionally coordinating with corrupt officials to allow the seizure of one of three shipments, creating the illusion of effective law enforcement (28). These transnational crime organizations are often involved in other crime trafficking, including humans, drugs, or weapons (28), making the dismantling of these networks extremely dangerous and complicated. Drugs are also reported to be offered as an alternative form of payment for pangolins (28).

Shipments of pangolin products then arrive at transport hubs, most commonly in Asia, such as Hong Kong and Singapore, where they are sold to local vendors before reaching demand hubs in East and Southeast Asian countries like China, Vietnam, and Cambodia (20, 32). A 2016–2019 analysis by the Wildlife Justice Commission's Intelligence Development Unit revealed that China, Nigeria, Vietnam, Singapore, Hong Kong, and the Democratic Republic of the Congo accounted for 94% of seized pangolin-scale tonnage (33). Upon reaching their destination, pangolin products are sold directly to customers as TCM or delicacies.

Key Nodes: Hong Kong and Cambodia

To meet the high demand for pangolin products in Asian markets, source communities in South Africa are often disproportionately targeted by the illegal wildlife trade due to the region's wide range of wildlife (27). In particular, Nigeria has become a prominent transport hub for pangolin trade, with genomic tracing showing that many scales originating in Central Africa are consolidated and exported through Nigeria rather than directly from their countries of origin (15).

Yet, the IWT is not limited to countries with increased biodiversity, with most states of the world playing a part in the export, transit, and/or import ot the IWT. Among these places is Hong Kong. Hong Kong serves as a key node in the IWT network largely due to its extensive port and air cargo infrastructure, free-port environment, and proximity to mainland China (34). While pangolins can be found in Hong Kong, it functions primarily as a transit and logistics hub, where trafficked pangolin products pass through local warehouses before moving to mainland China and other regional markets (35). In Hong Kong, there were 11 seizure records in 2019, totaling 8,940 kg of pangolin scales, worth around $5.6 million USD (36).

A once-emerging trafficking hub, Cambodia has now become one of the most recognized IWT hubs. It serves as both a source country and a transit hub connecting markets across Africa and Asia by land, air, and sea transport (37, 32). An investigation by the US-based conservation organization Earth League International reveals the trafficking of pangolins and other species through a network of shops, restaurants, and hotels that serve the Cambodian and Chinese elites in special economic zones like Phnom Penh. Backed by corrupt government officials and local crime organizations, the distribution of wildlife products across the Lower Mekong region is facilitated by nine major operations that form part of a regional trafficking network (32). Widespread corruption and ineffective enforcement of legal frameworks have allowed wildlife trafficking in Cambodia to remain highly lucrative.

During the 2025 ELI investigation, it was reported that a Cambodian restaurant owner allegedly advised undercover investigators to purchase local powdered pangolin scales and resell them in China for nearly three times the purchase price (32). Approximately 71% of all seized pangolin products were destined for China between 2007 and 2018 (38). It is without a doubt that China remains the largest market driving the IWT, and that the prominence of wildlife ingredients in TCM is a key driver of this market.

Current Conservation Methods

Current conservation methods for the pangolin address multiple stages of its illegal trade, including poaching interception, law enforcement anti-trafficking investigations, and community education. Organizations such as the Pangolin Crisis Fund run rescue and rehabilitation programs for confiscated pangolins while assisting agencies in investigating pangolin trafficking routes (39). Conservation methods such as camera trapping and mark-recapture for burrow-dwelling species have helped close the gap in our knowledge of pangolin ecology (40). In protected areas, rangers patrol and confront both local poachers and armed poaching groups to protect pangolins.

While anti-poaching and pangolin detection projects are essential, they do not disrupt the logistics networks that move scales from source countries through transit hubs to consumers. Currently, pangolin conservation is largely hindered by limitations in legal enforcement. There is a pressing need to strengthen detection along trafficking routes, shifting our attention beyond individual poachers to targeting larger illegal wildlife trade networks.

Rather than focusing solely on individual poachers, targeting the coordination and financing of large trafficking networks is more efficient, as it disrupts the movement of more shipments. Investigating these networks uncovers hidden beneficiaries, traces illicit income streams, and generates evidence/intelligence that allows authorities to anticipate criminal activity and keeps evidence for legal enforcement (41).

From a humanitarian standpoint, conservation needs to account for the socioeconomic conditions that result in economic disparities in the IWT. The number of actors involved in trafficking ranges from five to more than fifteen people, and the price each actor earns increases the closer one gets to the consumer. Poachers at the beginning of the supply chain receive substantially less for pangolin products than the intermediates/ crime networks do, yet they face the heaviest risk. A representative example, in Uganda, intermediate sellers receive four times the price per kilogram paid to poachers (20). However, the individuals arrested at the scene are often poachers or couriers. EIA reports reveal that law enforcement often also predominantly concentrates on the lower levels of the illegal wildlife chain, where poachers who are arrested are incarcerated, and their families face further hardship (42). Moreover, for most hunters, their involvement in pangolin trafficking stems from financial need and limited access to alternative livelihoods (43).

These socioeconomic pressures help explain why people turn to poaching, but they do not justify breaking the law or the harm it causes to ecosystems. Rather, they highlight the need to complement anti-poaching efforts with investigations targeting the higher levels of trafficking networks, an approach that is both more effective and more humane..

<u>An Innovative Approach to Wildlife Detection: APOPO</u>

According to UNODC, more than 780 million shipping containers move each year globally, yet fewer than 2% are inspected. Current screening methods, including X-ray scanners, detection dogs, and smart sensors, methods that are costly and time-consuming, limiting how much cargo can be checked. X-ray scans reveal the shape and density of the contents, but images of dense or overlapping cargo depend heavily on operator interpretation, and suspicious results often require opening and unloading the container. Detection dogs are effective but, because of their size, cannot reach narrow spaces or be lifted to scan stacked cargo or vents of sealed containers. Scent-detection rats, by contrast, combine a highly sensitive sense of smell with a small body size that allows them to adapt to these conditions.

APOPO's wildlife detection rats are African giant pouched rats trained to detect the scent of five trafficked wildlife products: pangolin scales, elephant ivory, rhinoceros horn, giraffe hide and hair, and African blackwood (ebony). HeroRATS are proven to be able to detect these items even if they are hidden among strong-smelling substances. In 2023, during a field trial at Dar es Salaam seaport, Tanzania, six rats participated in a double-blind wildlife detection project, detecting an incredible 83% of wildlife targets, even though trainers and researchers did not know which items contained wildlife products. Wildlife detection rats demonstrated their potential to search cargo inside opened containers and screen sealed containers while adapting to real port environments. The results of this trial have revealed their potential as a non-disruptive and cost-effective screening method to combat the IWT.

Wildlife detection rats In Action:

The APOPO wildlife detection program trained rats to identify wildlife products through positive reinforcement and reward-based scent discrimination. A brief description of the training process is as follows:

Socialized rats were first trained using a semi-automated apparatus with sniffing holes, with scent samples placed beneath each hole. Rats signaled detection of the product by maintaining a nose-poke in the target scent-sampling hole for a certain period. This training was supported by positive reinforcement, with the apparatus producing a food pellet in response to a correct answer. As training continued, researchers introduced non-target materials, new specimens, and mixtures of wildlife products in double-blind experiments to prepare them for real-life searches.

All training for this program was approved by Sokoine University of Agriculture's Institutional Committee for Research Involving Animals, with training sessions capped at 20 minutes to ensure animal wellbeing. Furthermore, wildlife detection rats involved in all programs are housed in spacious, well-ventilated enclosures that comply with international animal welfare guidelines. Their diets, stimulation, and health are closely monitored by APOPO staff and professional veterinarians. Moving the rats from the laboratory to real-world screening involved several stages. The first study, conducted in a controlled setting, showed that rats can reliably distinguish wildlife products from other materials (1). Building on these results, the rats were trained to search in simulated scenarios that replicate conditions found in warehouses, shipping containers, and luggage. The next transition was to introduce the rats to real operational settings for further training and evaluation.

Once working in these settings, the rats were tested to validate their performance and establish their operational accuracy. The most recent internal evaluation showed that rats can work effectively in both warehouse and airport settings [unpublished data]. Their small size allows them to search spaces that people and dogs cannot reach, such as the ventilation openings of shipping containers, so containers can be screened without being opened or emptied (44). In this evaluation, the rats correctly detected 85% of wildlife items with a false-positive rate below 5%, a level of accuracy comparable to that of detection dogs [ref]. The next stage of the program is to train rats on additional wildlife products, broadening the range of concealed items they can detect.

This 2017-2021 proof-of-concept study validated the ability of wildlife detection rats to detect illegal wildlife products and to retain this ability over time following training. Even after five to eight months, wildlife detection rats were still able to identify illegal wildlife products, demonstrating robust long-term scent memory (1).

At a Tanzanian seaport, wildlife detection rats, because of their small size, can reach small areas, such as the ventilation systems of shipping containers, that people or detection dogs cannot reach. Additionally, wildlife detection rats can detect wildlife products without personnel ever having to open or empty a container (44).

Integrating APOPO to Cambodia & Hong Kong

Cambodia and Hong Kong are two of the most important nodes for illegal pangolin trade. Hong Kong seized the carcasses and scales of up to 110,000 pangolins between 2013 and 2019 (45), while having nine container terminals and a single collective maritime infrastructure, the Port of Hong Kong (46). Cambodia, on the other hand, has 119 ports nationwide, comprising 31 seaports and 88 river ports, with 4 serving as international gateways (47,48). Illustrating the ongoing threat to these chains, in February of 2026, Jakarta authorities seized 3,053 kg of pangolin scales en route to Cambodia (49).

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