Department for Environment Food & Rural Affairs

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Illegal Wildlife Trade (IWT) Challenge Fund Final Report

IWT Challenge Fund Project Information

Project reference	IWT039
Project title	A novel system to detect illegal wildlife in shipping containers
Country(ies)	Tanzania (APOPO) South Africa (EWT)
Lead organisation	Endangered Wildlife Trust
Partner institution(s)	APOPO
Total IWT grant value	£125,158
Start/end dates of project	April 2017 – October 2019
Project leader's name	Ashleigh Dore
Project website/blog/social media	www.ewt.org.za; www.apopo.org
Report author(s) and date	Ashleigh Dore (EWT), Cindy Fast (APOPO), 31 January 2020

1. Project Summary

Shipping containers are moved in large numbers through busy international seaports and, from seizure information, ports are a known route for smuggling large volumes of wildlife. They represent a particularly challenging environment for law enforcement officials as current methods of screening shipping containers are expensive, time consuming, and potentially disruptive to port operations.

The aim of our project was to examine a novel detection system suitable for the port environment – using African Giant Pouched Rats (*Cricetomys ansorgei*) to detect pangolin derivatives (scales) and illegally logged African Blackwood (*Dalbergia melanoxylon*) in shipping containers. While this project primarily focused on deterring the trafficking of pangolins through enhanced detection, the rats had previously been trained to detect the *Dalbergia* timber species, so we continued this training to better assess the broader wildlife detection abilities of these rats, on the premise that this would enhance deterrence efforts at these ports. Our project followed a four-phase approach:

1. Proof of concept, for which we received matched funding from the United States Fish and Wildlife Service (USFWS), to test if the rats can discriminate between target (pangolins and hardwood) and non-target scents;
2. Advanced training with complex scent mixtures, including masking agents commonly used by smugglers;
3. In-depth psychometric analysis of the rats' sensitivity and specificity in detection of target samples, including identification of the minimum concentration of target among masking agents; and
4. Development and trialling of detection systems feasible for deployment into operational port environments to monitor and evaluate typical workplace-based performance of the giant pouched rats.

International bodies such as the CITES Secretariat and the IUCN regard pangolins as the most illegally traded wild mammal in the world.[1] The African Pangolin Working Group reported that, for the year 2016, just under 19 tonnes of pangolin scales were seized. This was the same year that pangolins were uplisted

[1] https://www.pangolinsg.org/

to CITES Appendix I, prohibiting commercial trade in pangolins. Illegal trade however has continued to escalate, with some 46 tonnes seized in 2017, and 39 tonnes seized in 2018.[2]

The illegal trade in pangolins has become a significant activity within organised crime worldwide and sub-Saharan Africa has not escaped the attention of these criminal syndicates. As a result, all species of pangolin are listed under CITES Appendix I and their conservation status ranges from Vulnerable to Critically Endangered. Illegal trade is the primary threat to pangolins in the wild. They are used in both African and Asian traditional medicines, and their meat is consumed as bushmeat or as a delicacy. Lesser threats include habitat fragmentation, electrocution on fences, and road deaths. This project addressed the primary threat to pangolins through improved detection and enhanced enforcement against illegal trade in pangolins.

Blackwood is frequently observed in Miombo woodland, which covers approximately 10% of the African continent and, since 1998, has been designated as Near Threatened on the IUCN Red List of Threatened Species. Since 2017, the trade of all existing *Dalbergia* species, including Blackwood, has been restricted worldwide by a CITES Appendix II listing.[3]

This project took place in Tanzania. While the project was not focused on community upliftment, there are communities within the project area that are directly impacted by wildlife trafficking. When wildlife trade is legal, sustainable, and well managed, it can benefit local communities, when it is poorly managed and largely illegal, however, benefits to communities are lost.[4] Pangolins exemplify this reality, due to illegal international trade, all pangolin species were uplisted to Appendix I in 2016, which made all commercial trade illegal. Further, crime and violence associated with the illegal wildlife trade can undermine government legitimacy, economic development, and social stability, as well as introduce economic losses to community members through associated crimes such as cattle rustling and drug dealing in affected communities.[5] A spike in crime could negatively affect the economy at multiple scales, resulting in a lack of willingness of investors and funders to invest in an area, and thus reducing broader economic opportunities available to rural populations. Depending on the outcomes, these circumstances can create or exacerbate social conflicts and social ills such as substance abuse and/or render sections of rural communities vulnerable or sympathetic to the financial support of poachers.[6] Finally illegal wildlife trade can directly encourage or finance civil conflict and insecurity and even cause localised weak economic development or exposure to price shocks.[7]

2. Project Partnerships

The Endangered Wildlife Trust (EWT) is a South African non-governmental, non-profit, citizen organisation dedicated to conserving threatened species and ecosystems in southern and east Africa to the benefit of all people. The EWT Wildlife in Trade Programme (WITP) Manager, Ashleigh Dore, served as the Project Leader and the main contact person for this project over the period December 2018 to date. Prior to then, Kelly Marnewick served as the Project leader and main contact, with Adam Pires as EWT WITP Manager. The Project Leaders were responsible for overall monitoring and evaluation and general oversight of the project. The EWT's WITP works to reduce trade-related threats that impact species' survival the wild, focusing on five thematic areas: prevention, detection, justice, governance and use. This project falls under the detection theme. Our programme remains very well positioned to engage with this project, and continued collaborations are planned to build on and extend the main findings of this project.

APOPO is a Belgian non-profit social enterprise that researches, develops, and implements scent detection technology, using rats, for humanitarian purposes such as land mine- and tuberculosis-detection. APOPO's main headquarters are in Tanzania where all research and training with the African Giant Pouched Rat (*Cricetomys ansorgei)* sniffer rats takes place. APOPO's trained sniffer rats are operationally deployed in Tanzania, Mozambique, Ethiopia, Angola, and Cambodia. The results of this ground-breaking and innovative work speak for themselves, including the destruction of more than 108,000 landmines and unexploded ordinances as well as more than 15,000 additional cases of tuberculosis detected by the rats to date. APOPO is the partner responsible for housing, training, and testing the rats for this project. Dr Cynthia Fast, APOPO's Head of Training & Innovation, serves as the project lead on behalf of APOPO.

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[2] https://africanpangolin.org/2019/05/22/in-the-news-africas-pangolins-caught-in-the-perfect-storm/

[3] Nakai, K., Ishizuka, M., Ohta, S., Timothy, J., Jasper, M., Lyatura, N. M., Shau, V., and Yoshimura, T. (2019). Environmental factors and wood qualities of African blackwood, Dalbergia melanoxylon, in Tanzanian Miombo natural forest. Journal of Wood Science 65, 39.

[4] Roe, D. 2008. The origins and evolution of the conservation-poverty debate: A review of key literature, events and policy processes. Oryx 42:491-503.

[5] Humphreys, J., & Smith, M. L. R. (2011). War and wildlife: the Clausewitz Connection. International Affairs, 87(1): 121-142.

[6] Gettleman, J., 2012. Elephants Dying in Epic Frenzy as Ivory Fuels Wars and Profits. New York Times, New York City.

[7] 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.

While APOPO are world leaders in training and managing detection rats, the EWT has expertise in the wildlife trade sector with active contacts in customs and ports authorities. As such, each partner had key strengths that contributed to the success of this project and formed a cohesive project team.

The partnership between the EWT and APOPO evolved from strength to strength. Our communications were primarily remote, due to the location of the two organisations, with APOPO in Tanzania and the EWT in South Africa, but regular communication with one another kept the relationship strong and the project moving forward. In addition to annual on-site visits to the project in Tanzania, all the project members joined in Dar es Salaam, Tanzania for a week-long workshop with port stakeholders in December 2018. Not only did the workshop strengthen the existing relationship between the EWT and APOPO, but it also secured buy-in for the project from the South African Revenue Service (SARS) and the Tanzanian Joint Port Control Unit. This is evidenced by an invitation from the Tanzanian Ministry of Natural Resources and Tourism to APOPO to participate in a 2-day workshop with port authorities and key stakeholders from Tanzania, Uganda, Kenya, Mozambique, Vietnam, and Dubai. These engagements, as well as the regular communication between the project partners and the law enforcement, strengthened the potential for working closely with these agencies as the project moves from concept to field application. APOPO and the EWT drafted this report jointly.

Finally, promising contacts were made when the EWT and APOPO presented details of this project at a side event to the CITES convention in Geneva ("*Harnessing tools and technologies for wildlife law enforcement*"). During the conference, we strengthened our relationships with the Singapore Port Authorities and they have continued to express interest in deploying rats in their port.

3. Project Achievements

3.1 Outputs

Each activity is numbered according to the output that it contributes towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1.

Output 1: Proof of concept that African Giant Pouched Rats can detect and discriminate pangolin scents.

Activity 1.1 – Appropriate training protocols were developed and implemented to train the rats to identify odours from target species (was fully completed in Year 1 of the project).

Despite a delay in obtaining pangolin derivatives for training samples, we relied on previous APOPO research that indicated our pouched rats could be rapidly retrained to detect novel odour targets. Thus, we avoided undue delay of the project by initially training the rats to detect a surrogate odour target (pure citrus oil), which enabled them to learn critical behaviours related to the scent-detection task, such as navigating the research equipment, indicating the presence of a target odour by holding their nose in a hole containing the target sample for a predetermined time, and ignoring non-target samples. After securing and preparing the pangolin scales (sun-drying and cutting into smaller samples) the rats were rapidly retrained with the pangolin and hardwood samples. The rats first transitioned to a different evaluation apparatus that provided more sensitive and precise measurement of their indication response (how long they held their nose over an odour sample) to enable more in-depth, psychometric analysis of scent detection performance. Concurrently with this transition, the rats were trained to detect the new targets (pangolin scales and hardwood pieces) at three different volumes (roughly translating to three levels of odorant concentration or "smelliness"). During this phase, we also introduced four novel non-target substances, including tree pods and seeds, washing powder, and unshelled peanuts (a tasty treat that the rats had to learn to ignore when working). We identified these common masking items (in addition to seven previously trained items, including seeds, coffee beans, synthetic hair wigs, woven cotton fabric, and cardboard) from CITES seizure data compiled by EWT (see Activity 2.1, below).

Activity 1.2 & 1.3 were designed to monitor and evaluate the rats' progression through training. These activities were fully completed by October 2018 (after approximately 9 months of training) with laboratory tests conducted to test the rats' abilities to discriminate between target species and control scents revealing the rats had (surpassed) 98% detection accuracy. During each of these training and evaluation sessions, the rats were presented with 100 samples of which only 12 were targets (six pangolin samples and six hardwood samples). These targets were randomly positioned among 88 non-target samples from ten masking agents commonly found in seized containers.

To simulate the operational environment, where human handlers cannot possibly predict the occurrence of a target, two of the targets within each session were coded as non-targets (i.e., they served as blind trials). To further mock the operational context where rats cannot be reinforced with food every time they find the target pangolin scales (because the presence of which would be unknown or unverifiable in real-time), rat indications on these blind trials were not rewarded with food.

During the final ten evaluation sessions, the team of rats detected 100% of the target samples. That is, the team found every single pangolin (60 in total) and hardwood sample (also 60), demonstrating perfect detection of the wildlife products. These targets included 20 samples (ten of each target) which the handlers themselves were not aware were targets (blinds trials), clearly showing that the rats relied on their noses to find these samples. Furthermore, the team of trained rats committed less than 1% false alarms (six indications) on the 880 non-target items presented within the same sessions (Figure 1). Operationally speaking, this suggests that the perfect sensitivity of the team did not come at a cost to efficiency by generating a substantial number of unnecessary searches. In other words, any container flagged by the rats as suspect of containing pangolin or hardwood derivatives would have a 99.4% likelihood of containing these items.

In another positive result, the average individual rat correctly responded on 97% of the 1,000 trials. Working alone, each rat correctly rejected 99% of the 880 non-target samples encountered across the 1,000 trials (Figure 1). This suggests the team results accurately reflect the individual abilities of each rat. This significantly strengthens operational feasibility because it suggests that a single rat could be deployed to screen cargo at any given time or location.

Collectively, these results clearly prove the concept that African Giant Pouched Rats can be trained to not only detect odours associated with pangolin derivatives, but also discriminate these smells from other items that could be routinely encountered in the shipping environment. These results provide strong evidence and lay a firm foundation for continued development of this rat scent detection technology as a screening tool to detect trafficking of illicit wildlife.

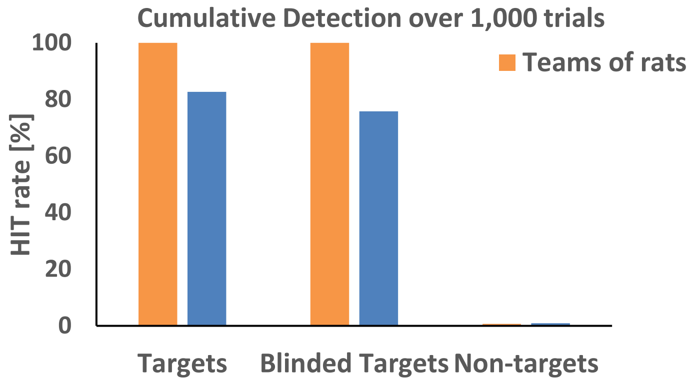

*Figure 1. After an initial nine months of training, the team of ten African giant pouched rats (orange bars) correctly identified 100% of all wildlife **targets** (60 each of pangolin scales and seized hardwood) while committing fewer than 1% false indications on **non-target** items (880 total non-targets comprised from ten different items identified from actual seizure reports). Trials with **blinded targets** (20 total) appeared as non-target trials to the human handlers and trainers, thereby requiring the rat to rely solely on its nose to detect them. Each of the ten rats (average rat depicted in blue bars) surpassed project goal by responding correctly (target hits and non-target rejects) during 97% of the 1,000 trials.*

Output 2: The African Giant Pouch Rats can detect pangolins and hardwood masked in other scents

Activity 2.1 – The *most common masking agents were identified from seizure data* during Year 1. The following materials were identified from CITES seizure reports and used as non-target controls during training: 1) electrical cables, 2) synthetic/plastic hair wigs, 3) new cotton socks, 4) coffee beans, 5) dengu (a native seed used in cooking), 6) cardboard, 7) washing powder, 8) *Delonix regia* (locally referred to as Krismasi or Flame Tree) seeds and 9) the seedpod casings of *Delonix regia*, and 10) unshelled, raw peanuts.

Activity 2.2 - *Procedures to tightly control sample mixture preparation and training procedures* were developed in Year 2. Although the photoionization detector (PID) purchased for this purpose failed to register many of the organic materials used, we developed an alternative procedure to control the "relative stinkyness" of the samples by using the mass of each sample substance as a proxy for odour concentration (please refer to Table 1 below). This technique resulted in unique volumes for each item. For example, a single unit of washing powder (quite smelly) contained less material than a single unit of electrical cables (relatively less odorous). Although this procedure is less precise than photoionization, the results of Activities 1.2 and 1.3 (reported above) and Activity 2.3 (reported below) demonstrate its success.

Table 1: Amount of each substance used to roughly approximate the "smelliness" between items. Smellier substances were presented in smaller volumes than less stinky items and these units were adjusted accordingly when presented in mixture. Bold items represent target items (pangolin and hardwood), while all others served as non-targets.

Sample item	Amount (g)
Pangolin	0.5
Seized Hardwood	1.5
Electrical Cable	8.0
Cardboard	1.0
Coffee beans	1.0
Dengu seeds	8.0
Peanuts (raw, unshelled)	1.0
Christmas Tree Seedpod	1.0
Christmas Tree Seed	8.0
Cotton Socks (new)	1.0
Washing Powder	0.4
Synthetic Wig	1.0

Activity 2.3 *Training on complex scent mixtures, including target scents mixed with commonly used masking agents* was fully completed in 2019, after an additional six months of training (three months for each target). During this training, we presented the rats with single odour samples composed of mixtures of two substances (relying on computed relative volume of each substance within the mixture to prevent any one odour overshadowing another, see Table 1 above). Some mixtures contained multiple non-targets presented together (such as coffee beans with washing powder), while others contained the target substance mixed with varying proportions of a non-target substance (for example, pangolin scales with coffee beans).

We first established the rats' untrained, baseline ability to find the targets when they encountered them "hidden" (mixed) among non-target masking items for the first time, by presenting each target in one of five ratios with non-target items: 1) 100:0 containing only the target and used for comparison of detection performance; 2) 50:50 or equal parts target and non-target; 3) 25:75; and 4) 10:90. To ensure the rat's indication behaviour was not driven by innate curiosity for the new odours, we also included samples of non-target mixtures (including all possible combinations of two items among the ten substances) as well as single non-target items for comparison.

This pre-test revealed that, remarkably, even without training, rats showed some ability to detect targets hidden in masking agents (Figure 2a), with the team of rats finding 67.5% of the 80 mixed samples (and maintaining their 100% detection of the trained targets when they occurred in isolation). The average individual rat successfully found 88% of the trained targets and 32% of the mixtures containing targets. Because the rats had never been rewarded for indicating any non-target items in the past, the fact that they hit any of these samples reflects the rats' keen sense of smell to pick out and identify the presence of the wildlife product "hidden" among the non-target material. Further support of this conclusion is provided by the average rat correctly rejecting 98% of the novel non-target mixtures, meaning it was not the mixtures themselves *per se* that motivated the rats to indicate them, but the actual presence of target material within the mixture.

Following the pre-test, rats continued training with these four mixture ratios for an additional 55 sessions (per target). Success of this training was evaluated with a final test that included a fifth mixture containing an even lower (05:95) target: non-target ratio than the rats had ever experienced before. This test revealed that our training successfully equipped the rats to find the targets even when they are just 5% of a mixture with other non-target items (Figure 2b, see also Section 3.1 progress on Output 3). Specifically, the team of rats found 86% of all target mixtures (including the untrained lowest ratio and blinded trials, as described in Activities 1.2 and 1.3 above), while committing less than 5% false alarms on all non-target items. Despite equivalent training, the rats were more successful at finding the pangolin scales (hitting 93% of mixtures containing pangolin and 100% of the scales when they were presented alone) than the seized hardwood (hitting 78% of hardwood mixtures and 92% of the samples containing only hardwood).

The same was true for the average individual rat who successfully found 61.5% of all target mixtures with slightly more pangolin (62%) than hardwood (60.5%) mixtures detected. Notably, overall detection rates improve when omitting the lowest (untrained) concentration, with the average individual rat finding more than 76% of all mixtures containing a target and fewer than 5% false alarms on non-target items (presented alone or within a mixture of another non-target substance).

Collectively, these results further bolster operational feasibility because illicit material is rarely, if ever, trafficked in isolation but is commonly hidden among masking items, such as the ones used here (as identified from actual seizure reports). According to our results, African Giant Pouched Rats can detect illicit material through masking agents. They can therefore serve as valuable detectors of illicit wildlife products.

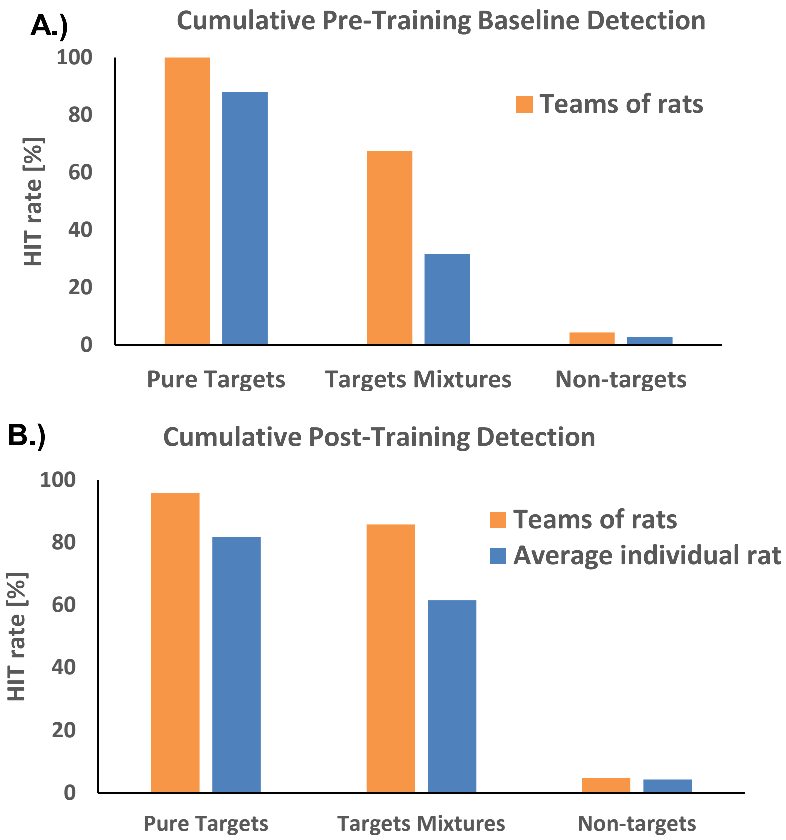

Figure 2. Trained African giant pouched rats working in a team (orange bars) or alone (blue bars) can find pangolin and hardwood derivatives "hidden" among other non-illicit items. A) Untrained rats were able to detect the targets mixed with some of the non-target items during a baseline test. B) After training, rats showed marked improvement in finding the hidden targets, including detecting them among all ten of the non-target masking agents. Not only did the team of rats (and average individual rat) find more of the hidden targets compared to pre-training baseline, they also reliably found them even when they constituted a smaller percentage of the overall mixture than they had ever experienced before (5:95, not shown).

Output 3: Feasibility of future operational application is assessed through in-depth psychometric analysis of the rat's sensitivity in detection of target samples, including identification of the minimum concentration among masking agents

Activity 3.2 – We *identified and analysed the psychometric properties of rat's pangolin and hardwood scent detection abilities* after all training was completed in 2019.

The three different volumes of each target used in Activities 1.1 and 2.2 revealed an initial preference of the rats to detect the largest volumes (1.5 g of pangolin scales and 4 g of seized hardwood), presumably because these samples were the strongest smelling. However, at the conclusion of training, all rats showed equivalent detection performance across the three volumes/concentrations, suggesting even 0.5 g of pangolin scales and 2 g of hardwood that had been seized by local authorities (and coated in a wax substance to conceal it) are easily detected by the rat's nose.

Nonetheless, without training, this same volume posed a challenge for the rats when it occurred along with equal parts of other items (50:50 ratio). The rats' ability to detect these amounts improved with training (see Activity 2.3 above), further suggesting that it does not constitute the lower limits of their olfactory capabilities. The rats still demonstrated superior detection accuracy of targets occurring in higher volumes (e.g. 50:50 compared to 5:95). It is, however, worth noting that the rats were never explicitly trained to find the 5:95 target ratio. Based on improvement from baseline with training on the other proportions, it is likely that the smaller target concentration does not represent the lower limits of the rats' abilities.

In most situations, illicit wildlife products are shipped in quantities higher than the low amount used in these tests (0.5 g used here, see Activity 3.3 below). Therefore, although we did not identify the rats' full olfactory capability to detect pangolin, we are confident that they could be used to detect illicitly trafficked target products in real-life situations.

Activity 3.3 – We further *assessed the translational relevance to real-life port activity by comparison to seizure data of illicit material among masking agents*). While the seizure reports did not include volumes of illicit and masking materials seized, media reports of pangolin scale seizures reflect substantial amounts (e.g., 14 tonnes in Singapore in April 2019, 230 kg in the DRC in March 2018, 6 tonnes in Tanzania in January 2017). Smaller seizures usually contain 1 kg or more.[8] The rats can detect substances as small as 5% of a mixture. Based on this knowledge, the rats could be expected to detect 1 kg of pangolin scales within a 20 kg shipment containing other masking materials. If we extrapolate this calculation to the 230 kg seizure in the DRC, the rats could have detected the illicit pangolin scales within a shipment weighing up to five tonnes.

Output 4: A system is developed to signal positive detection of pangolin to the rat handlers in a simulated operational environment (i.e. one that simulates conditions for screening containers in a seaport).

Activity 4.1 –Through discussions held at two workshops involving key stakeholders and port authorities in Tanzania in 2018 and 2019, the EWT and APOPO identified six potential deployment systems for the rats. Notably, these systems have the rat working within a self-contained environment (mobile rat lab or a portable container that could be deployed with or without the use of an elevator), or outside the ports (with courier facilities or passenger baggage and cargo). Because these systems do not expose the rat directly to the external environment (either within a port or not), there was no need to develop a mock port environment and habituate the rats to it. That is, the rats themselves would not be aware of their external environment when working with the developed deployment system. Thus, additional training to acclimate the rats to these potential external situations was unnecessary. As such habituation of the rats to a mock port environment was no longer necessary for this project.

The only exception was one of the potential deployment strategies, which closely mirrors a current strategy used with detection dogs. In this case, rats are deployed in shipping containers already flagged as suspect by other screening methods. While feasibility of this deployment system could benefit from trialling with shipping containers, initial testing of the supportive technologies (e.g., microswitch, rat backpack) has been completed without the need for a mock environment and made use of one shipping container readily available at APOPO's training centre.

Activity 4.2. – *Assessment of equipment needs to operate in a port environment*. The equipment needed to operate in a port environment was assessed over the course of this project, most notably during workshops held in December 2018 and July 2019. While accurate detection of targets is of utmost importance, it is also highly relevant that trainers and handlers correctly identify what the rat is communicating through its behaviour and that this behaviour can be identified despite potential physical barriers that might be encountered in the port environment. The rats serving in Activities 1, 2, and 3 were trained in a standardised lab environment, which allowed for controlled testing of various concentrations of the novel wildlife targets. Here, rats indicate the presence of a target substance by keeping their snout in a sample hole for a specific duration (e.g., 3 seconds; see Figure 3). However, with the exception of a mobile rat lab combining remote scent tracing techniques that were not been explored or funded in this project, it will not be possible to use this apparatus in a port environment.

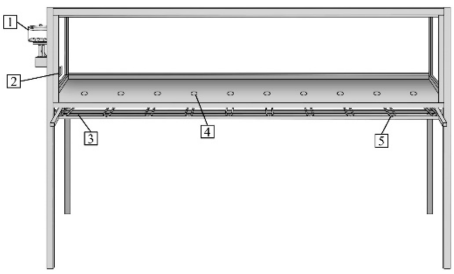

Figure 3. APOPO's semi-automated line cage used for the laboratory trials conducted throughout this project. The evaluation cage contains a (1) mechanism for delivering flavoured food pellet rewards to the rats through a (2) small magazine opening on one wall. Cassettes (3) containing up to ten different samples are loaded under the floor of the cage. The rat sniffs these samples in succession by inserting its nose in each hole (4) of the cage floor positioned directly above the sample, one at a time. (5) Retractable metal plates are opened and closed by the human handler to expose/cover the odour holes for the rat. Rats are trained to hold their nose within the odour hole for ≥3 seconds when the hole contains a target item but not when it contains a non-target item.

We have developed the following equipment to support six potential deployment strategies. The equipment falls into two broad categories: 1) rat-wearable technologies that can be used alone or in tandem with 2) transportation and evaluation systems.

[8] https://eia-international.org/wildlife/wildlife-trade-maps/illegal-trade-seizures-pangolins

1) Rat-wearable technologies

Rats were successfully trained to perform a novel indication response using a newly developed harness equipped with a microswitch. The microswitch allows the rat to directly and unequivocally communicate to a human handler that it has detected an odour target by pulling a small ball which activates an unambiguous auditory signal – a clearly audible *beep*. This means that the rat can tell its human handler when it has found wildlife products, even if the handler cannot physically see the rat. This device could easily be worn by rats working within a self-contained environment (such as a portable device or on an elevator) or in an enclosed area, such as a shipping container.

Prototype of the microswitch.

Additionally, APOPO collaborated with an MIT professor to create a functional tracking system prototype, that allowed rats to be tracked real-time while searching areas up to 200 m^2. The system uses ultra-wideband technology to track the rat's position in 3D space to the closest centimetre, thereby removing the need for expensive GPS while providing z-coordinate information that could prove especially helpful if the rats are stationed on an elevator system. Rat position relative to boundary tags is communicated real-time on a tablet or other smart device where a trainer or handler can easily code/interpret rat behaviour. The micro-switch (described above) could conceivably communicate directly with the handheld device to not only log rat position and trace path history, but also to flag precise coordinates where the rat has detected wildlife products.

Prototype rat backpack.

Finally, APOPO collaborated with an electrical engineering student at the Eindhoven University of Technology to develop a technology-enabled miniature backpack equipped with a video camera, microphone, accelerometer/gyroscope (for tracking/positioning functionality), and a long-range antenna. As with the micro-switch and tracking systems described above, this backpack could allow a free-range rat to be tracked while communicating to a handler what it is seeing. Future prototypes could even incorporate a micro-switch within the backpack to allow the rat to indicate what it smells while it searches defined areas.

2) Transportation and evaluation systems

Building on the design successes of the line cage apparatus used in the proof-of-principle lab trials (completed in parts 1–3 of this project), APOPO developed a fully automated version of this apparatus. As with previous versions of the line cage, this novel apparatus has ten holes along the floor, under which odour samples are placed. The rat smells each sample in succession and is rewarded with a tasty food reward when it correctly identifies the target sample. In this cage, the rat itself opens and closes these odour sampling holes. Photobeams, aligned within the hole, detect the rat's nose and solenoids controlled by custom software that smoothly and reliably slide open and close the doors covering the holes, while small LEDs signal to the rat which hole should be visited next. When a session begins, the handler simply loads the samples and starts the session on the computer, and the rat does the rest. This exciting development means that fewer (and less skilled) human handlers are required to manage a rat search in a mobile lab unit.

As noted above, the mobile lab unit would require additional support from remote scent tracing technologies. Although these technologies and equipment exceed the scope and budget of the current project, we completed a rudimentary analysis of feasibility by presenting our trained rats with filter papers that had been stored along with target and non-target items. Results from this preliminary test suggest the rats can be trained to evaluate these new sample materials to detect the presence of target items.

Another novel apparatus, which involves training the rats to press a lever in a portable chamber whenever they detect a target odour, was fully developed and trialled during this project. This apparatus could be particularly useful in a port environment to keep the rat in a protected and contained area while easily transporting it to various odour sampling areas, such as vent holes of shipping containers. The chamber can be placed on a small elevator (or forklift) system, granting the rat access to stacked shipping containers or positioning the rat in its mobile unit alongside existing technologies, such as X-ray scanners.

This apparatus was successfully tested with 20 rats that learned to press the lever in about one week of training. Further refinement to training protocols and apparatus to promote mobility is needed before this system is deployed.

Activity 4.3 – The *construction of the required equipment* was completed and their *indication system feasibility was assessed* (Activity 4.4) during Year 2 of this project. In addition to the descriptions provided for Activity 4.2 (above):

Microswitch and tracking system

Five young rats were successfully trained to use a prototype of this device. The rats' success demonstrates the feasibility of the device and supports further development. For example, should such a device be deemed suitable for use in the port environment, the microswitch could be wired to transmit an ultra-wideband signal to a trainer's handheld device that could include additional information such as precise location relative to other ultra-wideband transponders (essentially reconstructing the port environment in a virtual grid). This could be potentially useful in situations where the rat is not within sight of the trainer.

Lever pressing in portable chamber

A commercially available operant conditioning chamber (Med Associates, Inc., St. Albans, USA) was customised to the size and requirements of APOPO's African Giant Pouched Rats (length 71 cm, width 53.3 cm and height 36 cm). To our knowledge, African Giant Pouched Rats have never been trained to press levers before. We successfully trained 20 rats in this task, thereby establishing clear feasibility from a training perspective.

Free-search detection strategy

In previous work, APOPO demonstrated that African Giant Pouched Rats can be trained to carry a small backpack without disturbing their scent detection work.[9] During Year 2 of this project, we capitalised on various collaborative resources and expertise to develop a backpack prototype equipped with a mechanism for communicating (camera feed, microphone, rat-activated micro-switch, and various tracking methods such as accelerometers, gyroscopes, GPS, and/or RFID chips).

Activity 4.5 – We explored some possibilities in determining other variables for the rats' successful detection, such as sample time in the container, container size, etc. While these variables will depend on the actual deployment scenario or location, we tested whether the trained rats could detect target smells presented on filter papers while ignoring filter papers soaked in non-target odours. This was a preliminary proof-of-principle for remote scent tracing. Filter papers were inserted into small pots with samples for periods ranging from two to four months. The filters were then removed and presented to the rats.

Impressively, the rats detected the filter papers that had been housed with target scents to a similar level as the real target samples themselves. Notably, the length of time the filter papers were stored with the sample material did not impact detection performance. The rats identified samples that were stored for two and for four months in equal measure. This suggests that the airspace around the illicit wildlife products (used in this project) can become saturated with the odour of these items. If this assessment is true, then the rats could be deployed to search recently packed items at courier providers just as successfully as searching shipping containers held in storage for long periods of time. Further training and research are needed to support these possibilities and explore what other variables may influence the rats' scent detection.

Output 5: Women, wherever possible, are included as project staff and are empowered and capacitated at both organisations

At the EWT, Ashleigh (and before her Kelly), served as Project Leader and was responsible for the day-to-day coordination of the project and general project management, overseeing the monitoring and evaluation component of the project. At APOPO, the project was supported by a team of 50% women, including the Head of Research and Innovation, Dr Cynthia (Cindy) Fast, with day-to-day research activities closely monitored and conducted by Dr Miriam Schneider and Ms Mariam Juma.

Several women, including junior scientists/students Dian Kuipers, Kate Webb, and Haylee Ellis, served as primary research technicians on this project. Men were also empowered through this project, as the remainder of the project team was made up by Eustachius Koba, Karim Chang'a, Alexander Iyungu. The project aimed to be inclusive and involve and develop skillsets for both men and women. The research technicians handle all day-to-day activities to ensure training progressed as planned, including

[9] La Londe, K. B., Mahoney, A., Edwards, T. L., Cox, C., Weetjens, B., Durgin, A., & Poling, A. (2015). Training pouched rats to find people. J Appl Behav Anal, 48(1), 1-10. doi:10.1002/jaba.181

coordinating daily training sessions, monitoring and evaluating results, and overseeing sample preparation and training procedures.

APOPO staff have logged 4,560 hours on the project to date. The EWT staff logged 625 hours. As part of the internal procedures for both the EWT and APOPO, each staff member undergoes a performance appraisal twice a year. This appraisal considers the performance over the reporting period and identifies areas of learning opportunities for each staff member.

3.1 Progress towards project Outputs

Output 1: Proof of concept that African Giant Pouched Rats can detect and discriminate pangolin scents.

Indicator 1.1 *The eight rats have more than 95% accuracy rate of indication on target species, in a set of at least 1,000 trials, in* ex situ *conditions versus control samples within six months after the commencement of training.* As indicated above, the team of ten trained rats successfully found 100% of targets presented across 1,000 trials, exceeding the target of 95%. Furthermore, the team of rats committed less than 1% false alarm on "control" (non-target) samples across these same trials, translating into a combined overall accuracy of 97.4%. The very low false alarm rat is especially impressive when considering the inclusion of highly desirable food stuffs (such as peanuts) as non-target samples. That is, the rats showed incredible restraint to not be distracted by, or react to, the presence of food.

Perhaps even more telling than team performance is the average performance of each individual rat. Here, we also exceeded our goal of eight rats meeting the 95% accuracy criterion, with all ten rats individually achieving an average accuracy of over 97% across the 1,000 trials (two rats even scored as high at 98.7%).

Output 2: The African Giant Pouched Rats can detect pangolins (and hardwoods) masked in other scents.

Indicator 2.1 The rats achieve an 85% success rate in detecting pangolin scent when mixed with at least one typical masking agent in 1,000 trails, within ten months of training

Results from the baseline test revealed that even without training, the rats showed some ability to detect targets hidden in masking agents (see Figure 2a above); however, after training, the rats could find these targets even when they were just 5% of the mixture (Figure 2b above). Notably, the rats only required six months of additional training to reach this impressive level of detection.

The results described in relation to Activity 2.3 (above) speak to the overall ability of the rats to find any hidden target (pangolin scales or seized hardwood) across all mixture ratios. Closer inspection of team and individual rat performance during the final test (this was trials that only contained hidden pangolin samples) reveal that the team successfully found 93% of all mixtures containing pangolin (as low as 5% pangolin), surpassing our original goal of an 85%success rate.

While the average individual rat only found 76% of the trained mixtures containing pangolin, the unique test situation that introduced new mixtures may have compromised their otherwise strong ability. We therefore analysed rat performance on mixtures containing only pangolin across ten training sessions (1,000 trials). To simplify this investigation, we restricted our analysis to only samples containing the lowest concentration of pangolin (10:90) during these training sessions. The team of ten rats found a staggering 97.6% of these samples (61 in total), despite training still ongoing at this time. Notably, this detection success included mixtures with all ten masking agents. With a single masking agent (a synthetic wig), the team successfully found 100% of the hidden pangolin scales, which comprised only 10% of the overall mixture. The average individual rat showed similar performance with a little over 72% of all 10:90 pangolin mixtures detected and 87.8% of the mixtures with the synthetic wig. We thus met our original objective with both the rat team and individual rats exceeding the 85% detection success.

Output 3: Feasibility of future operational application is assessed through in-depth psychometric analysis of the rat's sensitivity in detection of target samples, including identification of the minimum concentration among masking agents.

Indicator 3.1 A concentration gradient, which determines the lowest threshold of ratio of one and/or two targets amongst five masking agents of the rats' scenting abilities, is established by month 15

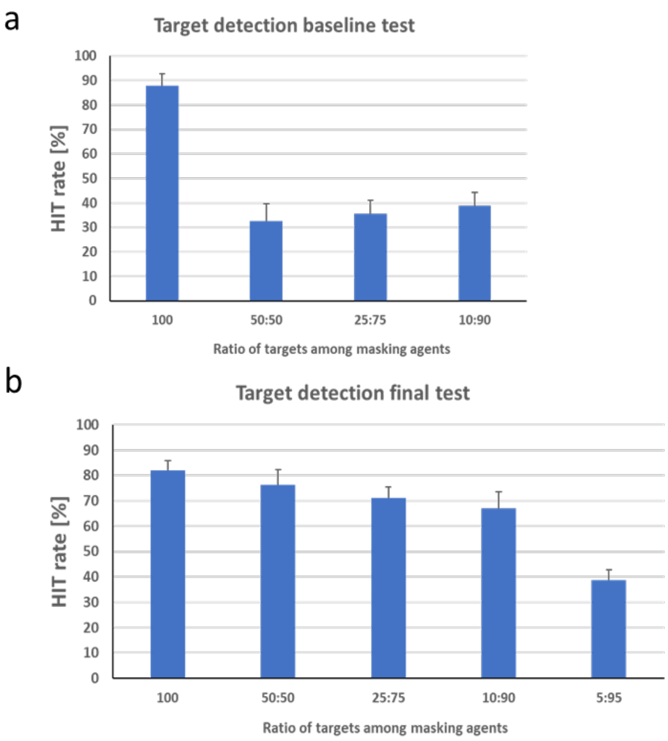

Figure 4. The detection success (hit rate) of individual rats related to the concentration (ratio) of targets appearing within a mixture of non-target masking agents. A) Although the untrained rats (baseline test) demonstrated some ability to find the targets, this was not concentration dependent until after training. B) Following training with the mixtures, the rats' success to find "hidden" targets markedly improved and a relationship between concentration and detection success emerged, with higher concentrations being detected at higher rates. Although the average rat found the 5:95 target mixtures less often than all higher concentrations, this may simply reflect the rats' untrained ability to find these low concentrations, rather than lower limits of olfactory capabilities.

This was accomplished in conjunction with the final test of the rats' ability to detect hidden targets (see description of Activity 2.3 above). Training was completed in a total of 15 months, including the initial nine months of training for Activities 1.1 and 1.2. Testing the rats with a variety of target concentrations (mixture ratios), revealed that the rats could detect the two targets (pangolin and hardwood) even when they comprised 10% or less of a mixture among all 10 masking agents (Figure 4). Notably, the rats even found the targets when they were presented in concentrations lower than what they had ever experienced before (5%; Figure 4b). Although detection of pangolin within mixtures was slightly superior to detection of the seized hardwood sample mixed with the same masking agents (not shown), the same pattern of increased probability of detection with higher target concentrations was demonstrated for both (77.3% hits at 50:50, 69.6% at 25:75, 60.5% at 10:90, and 37.5% at the novel 5:95 ratio of pangolin:non-target; and 79% hits at 50:50, 67.8% at 25:75, 61.3% at 10:90, and 30.8% at the untrained 5:95 ratio for hardwood:non-target mixtures).The improvement in detection rate from pre-training baseline (shown in Figure 4a) to post-training test (Figure 4b) suggests that the minimum concentration (here, the untrained 5:95) could likely be reduced even further with additional training. It is further worth noting that while attempts were made to equate odour strength across all material, the rats did appear to have more success finding targets mixed among some masking agents compared to others. Thus, the concentration gradient may depend on the specific mixture identity.

Output 4: A system is developed to signal positive detection of pangolin to the rat handlers in a simulated operational environment (i.e. one that simulates conditions for screening containers in a seaport).

Indicator 4.1 All eight rats can give their handlers an indication of a positive target scent within 15 months of training, with an obvious three second or more detection behaviour (e.g. scratching).

As described in the outputs of each activity above, not only did all ten rats successfully learn to hold their nose for three seconds over target items during the initial nine months of training, we also developed a variety of deployment systems which each have their own indication response and training timeline that fell well within the 15-month goal.

Nine other rats were successfully trained to similarly indicate when they detected target odours in the fully automated version of the apparatus used in Activities 1–3 within a period of three months.

The portable chamber requires the rat to press a lever to signal to a human handler and earn a food reward. Despite no known reports of African Giant Pouched Rats pressing levers, we successfully trained 20 rats to make this response within about a week. Additional training would be required to train the rats to only press the lever in the presence of a target substance in the absence of other materials. This level of scent detection training, however, is not directly related to the indication response of pressing the lever.

Additionally, all five of the young rats trained to interact with the microswitch attached to a harness mastered this ability and reliably triggered the device when they found hidden odour targets while searching areas up to 200 m^2. This training was conducted in conjunction with other scent detection training and was fully completed within nine months.

Finally, four rats were trained within weeks to carry the prototype backpack while they explored open swathes of land and navigated various obstacles and terrain (including a tunnel to simulate tight spaces in a fully packed shipping container). The long-range antenna proved successful at transmitting audio-visual feed from the backpack through the walls of a shipping container and at distances beyond 500 m.

Output 5: Women, wherever possible, are included as project staff and are empowered and capacitated at both organisations

Indicators *5.1 At least three women staff are assigned with project specific responsibilities at APOPO with at least 250 work integrated learning hours logged during project implementation, mentored by the Head of Training & Behavioural Research;*

Two women at APOPO served as principle investigators for the project. Dr Cynthia Fast (the Head of Training & Innovation) and Dr Miriam Schneider (Senior Researcher). In addition, one female rodent trainer was intimately involved in daily training and care of this project's animals. To date, a total of 4,560 work hours have been logged on the project, with more than 320 learning hours, including mentoring, capacity building, and workshop attendance.

5.2 At least one woman staff member is assigned with project-specific responsibilities at the EWT with at least 250 work integrated learning hours logged during project implementation, mentored by the EWT Wildlife in Trade Programme Manager.

Throughout the course of this project, there was always at least one EWT woman staff member directly involved in the project. In total, 625 hours were logged on this project.

3.2 Outcome

Outcome indicators

0.1 A minimum of eight rats reliably detect pangolin (and hardwood) products mixed among other masking odours within six months after the commencement of training.

This outcome was fully achieved with all ten rats detecting pangolin and hardwood products reliably, even when the products are hidden (mixed) among masking agents. During the final training session, the team of rats found 90% of all targets mixed with masking agents. To reach this level of mastery in finding hidden targets, the rats required 55 training sessions conducted over three months for each target. This falls well within the six-month goal.

0.2 Rats are shown to be 50% more cost-effective as detection agents than other methods, such as detection dogs, measured over 12-month cycle.

Table 2. An overview on the differences between detection rats and dogs.

Details	**Rats**	**Dogs**
Time to train	9 months[10]	3 to 6 months[11]
Longevity	7–8 years	7–8 years
Cost to train	< R 34,000	<R 100,000
Trainer qualification	On-the-job	Specialist
Handler specific	No	Yes

[10] Rats can commence training at 12-weeks old
[11] This is conservative, it heavily depends on the standard of the dog and handler. The dogs can commence training at 9-12 months old.

0.3 *At least 50% of the project team is female*.

The project team surpassed this goal with four women and three men comprising the team from APOPO and no less than 50% women comprising the EWT team at any stage of the project. Over the total project period, the total project team comprised of 64.3% women and 35.7% men.

3.3 Monitoring of assumptions

Assumption 0.1: Successful proof of concept phase.

Comments: This assumption was validated and upheld with successful completion of the proof of concept phase. The rats can accurately discriminate between the targets and non-targets, can detect multiple targets and can detect targets of varying concentrations

Assumption 1.1: Rats have a sufficiently good sense of smell, and are trainable

Comments: We have successfully supported this assumption. The rats showed near-perfect discrimination at the conclusion of training, as a testament to both their sense of smell and trainability. The rats possess an incredible sense of smell and can detect pangolin and hardwood even at 5% of the sample mixture. Furthermore, they can be trained to perform a variety of actions to signal to a human handler what smell, and to ignore desirable foods such as peanuts.

Assumption 2.1: The proof of concept was successful.

Comments: The rats showed that they can detect pangolin (and hardwood) while ignoring other, non-target substances. Please see the above discussion at Output 2, Section 3.2, which confirms that rats can find pangolin derivatives hidden among other items. A baseline test revealed the rats could detect the targets hidden among non-target items. After training, the rats showed marked improvement in finding targets hidden among all non-targets. Thus, this assumption has been upheld.

Assumption 2.2: Masking agent(s) used are synonymous with current smuggling trends including pangolins.

Comments: The masking agents, or non-targets, were identified by the EWT from the CITES Wildlife Seizure Database.[12] The database is comprised of open-source seizure reports, documented since 2012 to 2018. Products most used to smuggle illegal wildlife, including pangolin, were selected from the reports and remain synonymous with current smuggling trends. This assumption has been validated.

Assumption 2.3: Masking agent(s) are equally inherently neutral odours to the rat as are pangolins.

Comments: Both the targets and nearly all the non-targets were inherently neutral odours to the rats, meaning they posed no conceivable biological relevance to the rats and the rats did not show any initial bias to either spend excessive time investigating (indicating) or avoiding any of the substances. The one exception was peanuts, which are a natural food item for the rats. Rats did show an initial preference for indicating (sniffing for more than 3-s) peanuts, however, this bias was eliminated with further training. The inclusion of peanuts as a masking item was meant to mock an operational setting, which may require the rats to ignore edible items with a high appetitive value while still working on the detection task. Despite the biological relevance of their smell (the attraction of food), the rats learned to ignore their presence during the detection task and to only signal the presence of pangolin and hardwoods (items that the rats did not show an initial bias towards).

Assumption 3.1: Seizure data indicates range in ratio quantities of illicit material to masking material

Comments: The seizure data did not provide volume measurements of items found, so this assumption was unverifiable; however, we worked around this challenge by referencing other publicly available reports of seizures involving pangolin products. We found that the ratios used for training realistically correspond to seized volumes. For example, 230 kg of pangolin materials were seized in the DRC in March 2018. The rats demonstrated that they could detect the presence of pangolin products even when they constitute as little as 5% of a total mixture. Based on this calculation, the rats could have detected the illicit pangolin scales in this seizure within a shipment weighing up to five tonnes.

[12] https://trade.cites.org/

Assumption 3.2: The rats can detect target odours from pangolins when they are presented in a mixture with common masking agents

Comments: We have successfully upheld this assumption, (please see Output 3.2 above). This assumption was supported during initial baseline assessment revealing that even without training, the rats could accurately find some percentages of pangolin products mixed within non-target, masking items. This ability was only enhanced and strengthened with additional training.

Assumption 4.1: The rats are able to access the mock containers

Comments: Discussions with port authorities and key stakeholders revealed the need to develop alternative deployment strategies whereby the rats may not necessarily directly search containers (see Output 4 above), thereby circumventing the need for a mock port environment. We nonetheless evaluated this assumption while trialling the rat-wearable backpack developed to support these alternative deployment strategies. Specifically, four rats successfully navigated both open and closely confined spaces while wearing a backpack prototype. Furthermore, the custom-engineered antenna within the backpack could transmit audio-visual information real-time through the walls of a shipping container.

Assumption 4.2: The equipment allows the rats to access and give an indication on mock shipping containers

Comments: This assumption was upheld through successful trials of both rat-wearable, transportation and evaluation system technologies (see text related to Output 4 above).

Assumption 5.1 Women staff are interested and available to participate in the project

Comments: This assumption was supported. Over the project period, women project members have taken numerous opportunities to present on the value and impact this project will have in combatting wildlife trafficking. This includes presentations on the project at the Southern African Wildlife Management Association's Annual Symposium, the 25th Annual International Conference on Comparative Cognition in Melbourne Beach, Florida, USA, and the Animal Behaviour Management Alliance annual conference in Portland, Oregon, USA, as well as showcasing the project at the 2018 London Illegal Wildlife Trade Conference and at CITES in 2019.

Assumption 5.2: Low turnover rate of women in these positions

Comments: This assumption was partially upheld. This project has seen high staff turnover, but it is noteworthy that the attrition rate does not differ significantly from that observed on other projects within the participating organisations. In particular, the junior researcher position at APOPO is viewed as a valuable mentee opportunity to serve as a launching board for these individuals to further pursue scientific careers. Indeed, two women that were previously involved in this project are now in the process of completed PhDs in related scientific fields.

3.4 Impact: achievement of positive impact on illegal wildlife trade and poverty alleviation

Impact as per application form:

A reduction in the illegal wildlife trade in pangolins, which would impact positively on poverty in communities affected by wildlife trafficking.

Project contribution to this impact:

As shipping containers are the only primary transcontinental route for transporting large volumes of goods, having an effective detection system in place will help to disrupt this route for the organised crime syndicates, who struggle to find an alternative for the volumes shipped by sea (should our work prove successful, the same principles apply to other illegally traded species). It is also important to note that the more detection systems in place, the harder it is to make use of corrupt officials, as the various detection layers work as a check and balance system when used by multiple teams. This applies equally to human error.

With this project, we have made a crucial step towards future deployment of the rats by proving the concept that they can be trained to detect wildlife products, even when they are hidden among other items commonly used to mask them. Although further work is needed to refine the prototype deployment systems developed with this project, our results strongly suggest feasibility and provide a solid foundation for launching *in situ* trials with the network of key stakeholders established through this project.

Once the rats are deployed, they could operate alongside other detection systems such scanners, providing an additional layer of screening, or they could foreseeably operate alone to facilitate faster screening processes. In either instance, the strong detection performance demonstrated by the rats in this project makes it conceivable that sniffer rats will contribute much to combating illegal wildlife trafficking.

An unexpected development was the potential application of the rats at wildlife reserves. A key application is the potential use of rats for monitoring vehicles for wildlife contraband and firearms at game reserve gates (though this aptitude has not yet been field-tested), thus providing an added level of security and contributing to preventing poaching. This possibility will be explored in the future.

Impact on poverty alleviation:

This project did not address poverty directly, but rather indirectly through: 1.) The creation of jobs for women in the project where six women and three men were employed in Tanzania directly through this project (over the full project period); and 2.) Improving local governance and the resulting impacts thereof on organised crime on communities.

When wildlife trade is legal, sustainable, and well managed, it can benefit local communities, when it is poorly managed and largely illegal, however, benefits to communities are lost.[13] Pangolins exemplify this reality, due to illegal international trade, all pangolin species were uplisted to Appendix I in 2016, which made all commercial trade illegal. Further, crime and violence associated with the illegal wildlife trade can undermine government legitimacy, economic development, and social stability, as well as introduce economic losses to community members through associated crimes such as cattle rustling and drug dealing in affected communities.[14] A spike in crime could negatively affect the economy at multiple scales, resulting in a lack of willingness of investors and funders to invest in an area, and thus reducing broader economic opportunities available to rural populations. Depending on the outcomes, these circumstances can create or exacerbate social conflicts and social ills, such as substance abuse, and render sections of rural communities vulnerable or sympathetic to poachers.[15] Finally illegal wildlife trade can directly encourage or finance civil conflict and insecurity and even cause localised weak economic development or exposure to price shocks.[16]

4. Monitoring of assumptions

The means of verification remained the same throughout the project and remained relevant to the measurable indicators of each outcome. As discussed throughout this report, the rats successfully detected both pangolin and hardwood. Most key indicators were defined by quantitative measures of rat performance. Data log sheets were recorded during daily training session that included the session duration and number of successful trials per rat, in addition to more detailed measures captured by the apparatus, including, precise sniff time on individual odour samples (as measured to the nearest 15 milliseconds using infrared photobeams and detectors) and number of behavioural indications committed in the presence of target and non-target substances. Through meticulous record keeping (employing automated means where possible), we accurately documented the total number of laboratory trials completed over the throughout each phase of this project, resulting in more than 350 training sessions (or roughly 3,500 laboratory trials) over the entire duration of this project.

Finally, most assumptions made at the outset of the project were upheld. In the few occasions (namely detailed seizure reports and mock port environment requirements) where assumptions were violated or deemed no longer necessary, alternative strategies were developed to ensure project objectives were met.

5. Project support to the IWT Challenge Fund Objectives and commitments under the London Declarations and Kasane Statement

The London Conference Declaration XIII

This project addresses this goal through investigating novel tools and techniques that can be used in strengthening enforcement. Once the rats are deployed in the port environment, they will better equip law enforcement officials by providing novel tools and techniques for detection of smuggling. Additionally, port officials will receive training on the use of the rats, thereby increasing capacity at the ports and building new skills within the enforcement agencies.

[13] Roe, D. 2008. The origins and evolution of the conservation-poverty debate: A review of key literature, events and policy processes. Oryx 42:491-503.
[14] Humphreys, J., & Smith, M. L. R. (2011). War and wildlife: the Clausewitz Connection. International Affairs, 87(1): 121-142.
[15] Gettleman, J., 2012. Elephants Dying in Epic Frenzy as Ivory Fuels Wars and Profits. New York Times, New York City.
[16] 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.

The London Conference Declaration XV

This project addresses this goal through borrowing international expertise from landmine and TB detection and applying it to wildlife smuggling. If rats are implemented in the port environment, then they can provide a useful tool in better detecting transnational crimes. Further, the value of collaboration between stakeholders was one of the main points raised in the 2018 London Illegal Wildlife Trade Conference. This project directly speaks to that, with NGOs from different nations working to assist law enforcement to combat illegal wildlife trade.

The Kasane Statement point 8.

This project actively addresses this by engaging with the Tanzanian Port Authority (the Joint Port Control Unit) on the potential for implementation of this project. This provides opportunities to focus on the ability of rats to detect wildlife products and to highlight the importance of wildlife crimes with the port authorities. Over the course of the project we have also garnered support of Port Authorities in "demand" countries. The Singapore Port Authority specifically is very interested in working with us in deploying the African Giant Poached Rats. CITES COP17 provided further opportunities to engage with the stakeholders in the transport industry raising awareness on the value of African Giant Poached Rats in enhancing detection capacity in ports.

6. Impact on species in focus

As pangolins are the most traded mammals on earth, any intervention that acts as a deterrent should benefit these species. This intervention focused on applying better detection probability at the point of export in the supply chain. This should discourage syndicates from targeting pangolins for profit and using shipping containers as a relatively easy way of smuggling their body parts out of Africa in large volumes. We have also engaged extensively with port authorities at the point of import to deploy the rats to these ports, thus strengthening detection capacity across the supply chain. The Singapore Port Authority specifically is very interested in working with us in deploying the African Giant Poached Rats Thus, this intervention will contribute to easing the pressure on pangolin populations from poaching by increasing the cost of doing business for the syndicates.

As shipping containers are the only transcontinental route for transporting large volumes of goods, having an effective detection system in place at ports will help to disrupt this route for the organised crime syndicates, who struggle to find an alternative for the volumes shipped by sea (should our work prove successful the same principles apply to other illegally traded species).

Different measures will need to be implemented to address other pinch points in the supply chain, these are however outside the realm of this project.

7. Project support to poverty alleviation

As shown above at Section 1, illegal wildlife trafficking can have a direct impact on communities and poverty. When wildlife trade is legal, sustainable and well managed, it can benefit local communities. However, when it is poorly managed and largely illegal, benefits to communities are lost.[17] This is particularly prevalent when organised crime and transnational smuggling networks become involved and may even provide financial incentives to groups who will use crime and violence to promote their cause.[18]

The poaching of high-value species provides very little to the bottom tier of the supply chain (local poachers or harvesters). Criminal elements that are attracted to wildlife crime in local communities promote social decay and poor governance, which exacerbates the poverty line. Poor people would not be able to engage in poaching if these organised networks did not exist to get the product to the end-user markets.[19]

This project has directly combatted poverty for the local Tanzanian men and women who are employed full-time as rodent trainers with APOPO. The women receive competitive salaries that are equivalent to male colleagues in the same position. They also receive medical and other benefits, including paid holiday leave, work apparel, on-the-job-training as needed, and even vouchers for lunch from a local vendor. Further, as the rats are not handler-specific, (so can be worked by multiple people) and the handler qualification is on-the-job training, employment opportunities will grow exponentially with the scaling-up of this project.

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[17] Roe, D. 2008. The origins and evolution of the conservation-poverty debate: A review of key literature, events and policy processes. Oryx 42:491-503.
[18] Lujala, P. & Rustad, S.A. 2011. High-value natural resources: a blessing or a curse for peace? Sustainable Development Law & Policy 12 (19–22): 56–57.
[19] Duffy, R. & St John, F.A.V. 2013. Poverty, Poaching and Trafficking: What are the links? Evidence on Demand DOI: http://dx.doi.org/10.12774/eod_hd059.jun2013.duffy

Tanzania is classified as a Least Developed Country (LDC), with high levels of poverty and unemployment. Tanzania's tourism industry, which focuses on safaris and wildlife, is the main foreign exchange earner for the country with about one million tourists a year. The global value of wildlife trade is estimated at US$300 billion per annum. Therefore, channelling this money into communities who share the landscape with wildlife through tourism and sustainable wildlife trade can form a key component of poverty reduction.

8. Consideration of gender equality issues

Over the project period, both APOPO and the EWT identified and assigned women staff to this project. Both organisations actively improve the status of women in the workplace by empowering them in our operations and promoting their activities and successes in our media campaigns. Further, as from 1 April 2018, all direct senior project roles in both APOPO and the EWT were taken up by women. Women team members are given equal opportunity, including capacity building and on-the-job training as their male colleagues. Further both the APOPO and EWT project teams work directly with men, the APOPO project team comprising of three men who work directly on this project.

9. Lessons learnt

A key lesson from this project is administrative in nature. It highlights the submission of change requests and the need for adaptive management where there are project delays beyond the control of the project team (for example delays in procuring certain materials from suppliers for the project). This includes anticipating changes/challenges in the future and taking a more proactive approach to address them. The support team within IWT have been incredibly helpful throughout the project period. We recommend to grantees that they participate in the valuable training sessions held by the IWT, and engage with the IWT team with direct queries.

Additionally, during the final stages of advanced mixture training, we witnessed a slight elevation in false indications to novel mixtures of non-target items (mixtures containing no targets but appearing in unique new ways). While this tendency did not substantially impact overall false alarms committed, it taught us to introduce more novel items to the rats throughout the training process – a lesson that has been incorporated into the next phase of the project.

9.1 Monitoring and evaluation

No major changes to the logframe were required. We did make minor amendments, approved through a change request. Where challenges arose (e.g., delays in procuring training materials), effective and efficient solutions were promptly put into practice (initially training the rats with a surrogate odour) to ensure primary objectives could still be met.

Slightly more significant changes were made to activities related to Output 4, wherein it was determined that construction of a mock port environment would be exorbitant, and we would not be able to replicate the high level of noise and activity in the ports. It was therefore determined that the construction of a mock port would provide little benefit, but that development of additional supportive technologies to aid rat deployment would be crucial. Both the EWT and APOPO immediately addressed this challenge by conceptualizing six different deployment strategies and evaluated their feasibility in conjunction with port authorities and stakeholders. As a result, a variety of rat-wearable transportation and evaluation systems were developed and tested.

Overall the M&E system proved practical and beneficial in identifying any potential challenges to enable swift and directed intervention. External feedback from workshops and a side event at the CITES meeting were overall very supportive, approving of our procedures and results, supportive of further development, but voiced concern over acceptance of the rats to work in the various environments where they could conceivably have the greatest impact. This feedback was helpful in developing the various deployment strategy trialled during this project to position the rat in a concealed and safe setting, regardless of where it is deployed.

9.2 Actions taken in response to annual report reviews

The reviews received for our annual reports were discussed within teams and between the partners (EWT and APOPO), and were found to be very constructive and helpful. It is worth noting that the detailed critique from 2018 guided development of the 2019 report. It was noted that all 2018 and 2019 concerns have been addressed in subsequent reports and in a separate document submitted with this report (please see annex 17).

10. Other comments on achievements not covered elsewhere

The EWT and APOPO recently committed to continued partnership in further developing the operationally feasible deployment systems identified during this project, with secured support and funding from the German GIZ, “Partnership Against Poaching and Illegal Wildlife Trade (in Africa and Asia)” initiative. Under the GIZ-funded project and in recognition of the initial proof-of-concept having been established this project, we will now trial deployment strategies in the shipping ports themselves. The IWT project was a strong catalyst for this intervention.

In an unrelated study at APOPO (under review), we found that the rats can be trained to detect five different odour targets simultaneously. We have thus used the networks established through this project (including the Tanzanian Wildlife Ministry and Tanzanian Wildlife Management Authority; TAWA) to explore the possibility of expanding the wildlife products the rats are able to detect, including rhino horn and ivory. A proposal to secure funds for this expansion is currently under review.

This project clearly established that trained African Giant Pouched Rats could serve as reliable detectors of illicit materials while ignoring other material. This was evidenced by the 98% successful detection rate when presented with 100 samples, 12 of which contained target items. As an additional measure of assessing operational feasibility (that extends beyond the scope of activities within this project), further research could explore if the rats are equally successful when the target items are less prevalent.

11. Sustainability and legacy

As above, the EWT and APOPO recently committed to continued partnership in further developing the operationally feasible deployment systems identified during this project, with secured support and funding from the German GIZ initiative. Under the GIZ-funded project and in recognition of the initial proof-of-concept having been established this project, we now trial deployment strategies in the shipping ports themselves.

The feedback from relevant parties (port authorities, behavioural scientists, wildlife trade experts, etc.) on this project has been overwhelmingly positive and, in December 2018, we received support for the operationalisation of the rat by both the South African Revenue Service and Tanzanian Joint Port Control Unit. This support will be formalised in legal agreements for the next phase of the project as detailed above in part 10, where the rats will be trialled in the ports themselves.

Funding from the IWT Challenge Fund has ensured that the project moved from the proof of concept phase to the current stage of assessing pre-implementation feasibility and deployment strategies, allowing us to secure funding for the in port trialling of the rats, with the end goal of full deployment of the rats in ports globally coming ever closer.

12. IWT Challenge Fund Identity

The IWT Challenge Fund is recognised in the EWT’s Integrated Report. IWT is also noted in the programme flyer we have developed that is distributed at all meetings and public events.

APOPO brands all mentions of its programmes with donor logos on our own channels, though achieving donor mentions in media articles and broadcasts is very difficult. Nonetheless, when fielding media requests and hosting visits, we always mention the support of the IWT Challenge Fund and UK Government.

When branding support of the IWT Challenge Fund, APOPO uses a logo that very clearly depicts the UK flag as well as the text 'funded by the UK government' beneath it. See for example APOPO’s recognition of IWT Challenge Fund in their published 2018 annual report (also shared on our website and social media outlets), which will also appear in APOPO’s 2019 annual report (in preparation). This recognition is in the project description on the Research and Development (R&D) section where the IWT Challenge Fund support was recognised as part of a larger programme and includes other partners and donors that support the research project.

APOPO’s R&D section of the website is currently undergoing revisions and we plan to include a list of funding sources with logos in the new version. However, we routinely publish articles or news stories surrounding ongoing projects and progress. Some examples of relevant articles found on APOPO's website include: APOPO presents at CITES, Ratting on wildlife crimes, British High Commissioner visits HeroRATs in training, and Focusing on R&D

Branded articles are also shared on our Social media channels, such as on our Facebook page.

APOPOs development of a robust online community (of currently over 150,000) has proven that our detection animals lend themselves well to engagement and loyalty needs of today's online audience – providing benefits in terms of profile-raising.

Please see Annex 18 for picture illustrations of the above.

The IWT Challenge Fund was also recognised in the awareness raising material developed for and distributed at CITES COP18 (see Annex 6A&B).

13. OPTIONAL: Outstanding achievements of your project (300-400 words maximum). This section may be used for publicity purposes

I agree for the IWT Secretariat to publish the content of this section (please leave this line in to indicate your agreement to use any material you provide here)

The illegal trade of wild species has determinantal effects on species survival, ecosystem stability, and social systems and security of affected communities. High profit margins and weak governance provide a breeding ground for corruption on every level of the illegal wildlife supply chain. To address this complex issue, the EWT and APOPO have partnered on proof-of-concept research to examine the abilities of APOPO's African Giant Pouched Rats to detect illegally trafficked pangolin scales and African hardwoods. This approach was based on the proven scent-detection technology using African Giant Pouched Rats (*Cricetomys ansorgei*) who are operationally deployed to detect landmines and tuberculosis by APOPO. The strong foundation of this scent-detection technology has proven adaptable for the detection of any substance with a unique odour profile that we have tested. With the present project we were able to prove that giant pouched rats can be trained to identify the smell of two illicit wildlife products from critically endangered species. Ten rats were trained to find pangolin (*Smutsia temminckii*) scales and African blackwood (*Dalbergia melanoxylon*), while ignoring common masking materials found in trafficking containers, such as coffee beans, seeds, or washing powder. The project also examined how well the rats detected fractions of target samples hidden within mixtures of common masking agents used to conceal wildlife contraband. Here the rats were even able to identify targets that constituted a mere 5% of the total mixture. This result shows promise for the rats to work in a real-life operational setting where smuggled wildlife products rarely (if ever) occur in isolation. This project provided substantial evidence for the concept that rats can be trained to detect wildlife products and built a firm foundation to further develop and pursue operationally relevant deployment strategies to position the rats in shipping ports.

14. Finance and administration

14.1 Project expenditure

Project spend (indicative) since last annual report	2017-19 Grant (£)	2017-19 Total actual IWT Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)				
Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items (see below)				
Others (see below)				
TOTAL				

Staff employed (Name and position)	Cost (£)
Adam Pires (replaced by Ashleigh Dore March 2019)	
Kelly Marnewick (M&E)	

Kelly Marnewick (Project lead)	
Alexander Iyungu	
Anthony Mshigen	
Bakari Mwenjuma	
Thomas Elias	
Lucy Bashekanako	
Haylee Ellis	
Ashleigh Dore	
Micaela Bernardez	
TOTAL	

Capital items – description *Please detail what items were purchased with fund money, and where these will remain once the project finishes*	**Capital items – cost (£)**
Photoionization Detector – Apopo, Morogoro, Tanzania Two laptops, accessories, EWT, Johannesburg, South Africa Direct Cargo sampling apparatus	
TOTAL	

Other items – description *Please provide a detailed breakdown for any single item over £1000*	**Other items – cost (£)**
Laboratory supplies (rubber gloves, wipes, methylated spirits, sample pots pipette tips, food reward pellets, etc) Audit fees	
TOTAL	

14.2 Additional funds or in-kind contributions secured

Source of funding for project lifetime	**Total (£)**
USFW Service	
TOTAL	

Source of funding for additional work after project lifetime	**Total (£)**
German GIZ “Partnership Against Poaching and Illegal Wildlife Trade (in Africa and Asia)” initiative	
TOTAL	

14.3 Value for Money

This project was an excellent value for money. Throughout the life of the project, whenever expenses were made, members of the team made sure to research the best value options for those purchases. This applies to the photoionization detector, laptops, accessories, and cargo sampling apparatus. Staff costs and consultancies were within acceptable local levels and commensurate with experience. When spending on travel and subsistence, value was considered, and reasonable decisions were prioritised by the staff.

Annex 1 Project's original (or most recently approved) logframe, including indicators, means of verification and assumptions.

Note: Insert your full logframe. If your logframe was changed since your application and was approved by a Change Request the newest approved version should be inserted here, otherwise insert application logframe.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: A reduction in the illegal wildlife trade in pangolins, which would impact positively on poverty in communities affected by wildlife trafficking.			
Outcome: The feasibility of a cost-effective, reliable and efficient screening method to detect illegal pangolin in shipping containers is assessed.	0.1 A minimum of 8 rats reliably detect pangolin (and hardwood8) products mixed among other masking odours within six months after the commencement of training. 0.2 The rats can be shown to be 50% more cost effective as detection agents than other methods such as detection dogs, measured within a 12 month cycle. 0.3 At least 50% of the project team is female.	0.1 Rats demonstrate high sensitivity (indicate even at low concentrations) and specificity (minimal to no false alarm indications) in detecting target items known to be hidden among masking agents (Annex 8). 0.2 Rats demonstrate equivalent accuracy (sensitivity and specificity) when the presence of targets are unknown (blind performance) (Annex 8). 0.3 Time to evaluate a set number of samples will be measured to further assess efficiency (Annex 8). 0.4 Detailed cost-analysis of training and maintenance per rat in comparison to the costs of a dog to achieve the same result (see Table 2). 0.5 Project staff organigram for both organisations	Successful proof of concept phase.
Outputs: **1.** Proof of concept that African Giant Pouched Rats can detect and discriminate pangolin scents.	1.1 The 8 rats have more than 95% accuracy rate of indication on target species, in a set of at least 1,000 trials, in *ex situ* conditions versus control samples within six months after the commencement of training.	1.1 Number of accurate indication logged against non-target controls (Annex 8). 1.2 Log sheet recording the duration of training for each trial and the number of successful trials, (at least 950; Annex 8). 1.3 Number of laboratory trials documented (Annex 8).	1.1 Rats have a sufficiently good sense of smell, and are trainable.

2. The African Giant Pouched Rats can detect pangolins and hardwoods masked in other scents.	2.1The rats achieve an 85% success rate in detecting pangolin scent when mixed with at least one typical masking agent in 1,000 trails, within 10 months of training.	2.1 Tightly controlled variations of target to non-target ratio odour mixtures are developed with stable PID measurements (see Table 1). 2.2 Number of accurate indications logged against non-target containing samples and mixtures (Annex 8). 2.3 Log sheet recording the duration of training for each trail and the number of successful trials, (at least 850; Annex 8). 2.4 Number of laboratory trials documented (Annex 8).	2.1 The proof of concept was successful. 2.2 Masking agent(s) used are synonymous with current smuggling trends including pangolins. 2.3 Masking agent(s) are equally inherently neutral odours to the rat as are pangolins.
3. Feasibility of future operational application is assessed through in-depth psychometric analysis of the rats' sensitivity in detection of target samples, including identification of the minimum concentration among masking agents.	3.1. A concentration gradient, which determines the lowest threshold of ratio of one and/or two targets amongst five masking agents of the rats' scenting abilities, is established by month 15.	3.1. Rat accuracy is reliably predicted by target concentration (Annex 8). 3.2 Number of accurate indications logged against non-target containing samples and mixtures (Annex 8).	3.1 Seizure data indicates range in ratio quantities of illicit material to masking material. 3.2 The rats can detect target odours from pangolins when they are presented in a mixture with common masking agents.
4. A system is developed to signal positive detection of pangolin to the rat handlers in a simulated operational environment (i.e. one that simulates conditions for screening containers in a seaport).	4.1 All eight rats are able to give their handlers an indication of a positive target scent within 15 months of training, with an obvious three second or more detection behaviour (e.g. scratching).	4.1 Rat accuracy is equally reliable across the initial training cage and the simulated operational environment (Annex 9). 4.2. Number of accurate indications logged against non-targets (Annex 8). 4.3. Detailed system documentation including apparatus design and indication standard operating procedures (Annex 10).	4.1. The rats are able to access the mock containers 4.2 The equipment allows the rats to access and give an indication on mock shipping containers.
5. Women, wherever possible, are included as project staff and are empowered and capacitated at both organisations	5.1 At least three women staff are assigned with project specific responsibilities at APOPO with at least 250 work integrated learning hours logged during project implementation, mentored by the Head of Training & Behavioural Research; 5.2. At least one woman staff member is assigned with project-specific responsibilities at the EWT with at least 250 work integrated learning hours logged during project implementation,	5.1 Project staff organigram for both organisations (Annex 12 and 13) 5.2 Terms of reference for each women staff member (Annex 14 and 15) 5.3 Time and project activity sheets for female project staff 5.4 Project monitoring and evaluation report (Annex 11, supplementing 6-month reporting to the IWT)	5.1 Women staff are interested and available to participate in the project 5.2 Low turn rate of women in these positions

	mentored by the EWT Wildlife in Trade Programme Manager.		

Activities (each activity is numbered according to the output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1)

1.1. Appropriate training protocols are developed to train the rats to identify odours from target species;

1.2. Laboratory tests are conducted to test if the rats are able to discriminate between target species and control scents; and

1.3. The rats have a 98% accuracy rate of detection.

2.1. Identification of the most common masking agents through a literature search of seizure data;

2.2. Procedures to tightly control sample mixture preparation and training procedures are developed; and

2.3. Training on complex scent mixtures, including target scents mixed with commonly used masking agents.

3.1. Determining the concentration gradient for rat scent-detection limits for pangolins;

3.2. Identification and analysis of psychometric properties of rats' pangolin and hardwood scent detection abilities; and

3.3. Assessment of translational relevance to real-life port activity through comparison to seizure data concentrations of illicit material among masking agents.

4.1. Habituation of the rats to a mock port environment;

4.2. Assessment of equipment needs to operate in a port environment;

4.3. Construction of the required equipment;

4.4. Assessment of indication system feasibility in a port environment; and

4.5. Determining other variables for successful detection by the rats, such as sample time in the container, container size, etc.

5.1 Identify woman staff willing to participate in the project;

5.2. Assign project specific roles and responsibilities;

5.3. Log time against project activities; and

5.4. Monitor and evaluate performance and learning for each woman staff member.

Annex 2 Report of progress and achievements against final project logframe for the life of the project

Project summary	Measurable Indicators	Progress and Achievements
Impact A reduction in the illegal wildlife trade in pangolins, which would impact positively on poverty in communities affected by wildlife trafficking.		With the present project we were able to prove that giant pouched rats can be trained to identify the smell of two illicit wildlife products from critically endangered species. Ten rats were trained to find pangolin (*Smutsia temminckii*) scales and African blackwood (*Dalbergia melanoxylon*), while ignoring common masking materials found in trafficking containers, such as coffee beans, seeds, or washing powder. The project also examined how well the rats detected fractions of target samples hidden within mixtures of common masking agents used to conceal wildlife contraband. Here the rats were even able to identify targets that constituted a mere 5% of the total mixture. This result shows promise for the rats to work in a real-life operational setting where smuggled wildlife products rarely (if ever) occur in isolation. This project clearly showed that rats can be trained to detect wildlife products and built a firm foundation to further develop and pursue operationally relevant deployment strategies to position the rats in shipping ports.
Outcome The feasibility of a cost-effective, reliable and efficient screening method to detect illegal pangolin in shipping containers is assessed.	0.1 A minimum of 8 rats reliably detect pangolin (and hardwood8) products mixed among other masking odours within six months after the commencement of training.	0.1 Our results show African Giant Pouched Rats can detect the smell of illicit material even when they are mixed with masking agents. 10 rats successfully found target material within masking odours after 3 months of training (for each target separately or 6 months training in total). Importantly, this training equipped the rats to find target material even when they were just 5% of a mixture with non-target masking items (see Annex 8 for rat data captured during training and test sessions). Notably, we found that even without training, rats showed some ability to detect targets hidden in masking agents. Because the rats had never been rewarded for indicating any non-target items in the past, the fact that they hit any of these samples reflects the rats' keen sense of smell to pick out and identify the presence of the wildlife product "hidden" among the non-target material. Nonetheless, this ability markedly improved with explicit training to detect targets occurring within mixtures.
	0.2 The rats can be shown to be 50% more cost effective as detection agents than other methods such as detection dogs, measured within a 12-month cycle.	While the time to train the rats is slightly longer than the time to train canines, the training costs are comparatively cheaper, and no specialist training is required for the handlers of the rats but is required for the canines. Further the rats can begin training from 12 weeks old, whereas canines only begin training between one to two years of age. All preliminary evidence shows that the rats are at least 40% more cost effective compared to canines.

	0.3 At least 50% of the project team is female.	Over the project period, the total project team comprised of 64.3% women and 35.7% men.
Output 1. Proof of concept that African Giant Pouched Rats can detect and discriminate pangolin scents.	The 8 rats have more than 95% accuracy rate of indication on target species, in a set of at least 1,000 trials, in *ex situ* conditions versus control samples within six months after the commencement of training.	We successfully trained 10 rats to reliably signal targets while ignoring non-target items. During the final ten evaluation sessions (including 1,000 total trials), the team of rats detected 100% of the target samples. That is, the team found every single pangolin (60 in total) and hardwood sample (also 60), demonstrating perfect detection (100% sensitivity) of the wildlife products. These targets included 20 samples (ten of each target) which the handlers themselves were not aware were targets (blinds trials), clearly showing that the rats relied on their noses to find these samples. Furthermore, the team of trained rats committed less than 1% false alarms (six indications or 99.3% specificity) on the 880 non-target items presented within the same sessions. Furthermore, during these same 10 sessions, the average individual rat correctly responded on 97% of the 1,000 trials and correctly rejected 99% (specificity) of the 880 non-target samples encountered across the 1,000 trials. Despite overall training success, initial delays in procuring wildlife samples for training did cause the training period to exceed our initial target of six months, with all training completed in a period of 9 months. Evidence is provided in section 3.1 and 3.2 of report and in Annex 8.
Activity 1.1. Appropriate training protocols are developed to train the rats to identify odours from target species;		All training protocols were fully developed and implemented to train the rats to identify odours from target species during Year 1. These protocols underwent routine revision for optimizing and/or to address new objectives of the phased training approach (e.g., training on target samples mixed with non-target items).
Activity 1.2. Laboratory tests are conducted to test if the rats are able to discriminate between target species and control scents; and		These activities were fully completed by October 2018 (after approximately 9 months of training) with laboratory tests conducted to test the rats' abilities to discriminate between target species and control scents revealing the rats had (surpassed) 98% detection accuracy with the team of rats showcasing an accuracy rate of 99.4%.
Activity 1.3. The rats have a 98% accuracy rate of detection.		
Output 2. The African Giant Pouched Rats can detect pangolins and hardwoods masked in other scents.	The rats achieve an 85% success rate in detecting pangolin scent when mixed with at least one typical masking agent in 1,000 trails, within 10 months of training.	Results indicate African Giant Pouched Rats can detect illicit material through masking agents.10 rats were successfully trained to detect target material within masking odours within 3 months of training (for each target separately, or 6 months total training). We analysed rat performance on mixtures containing only pangolin across ten training sessions (1,000 trials). To simplify this investigation, we restricted our analysis to only samples containing the lowest concentration of pangolin (10:90) during these training sessions. The team of 10 rats found a staggering 97.6% of these samples (61 in total), surpassing our target of 85%. Notably, this detection success included mixtures with all ten masking agents. With a single masking agent (a synthetic wig), the team successfully found 100% of the hidden pangolin

		scales, which comprised only 10% of the overall mixture. The average individual rat detected 72% of all 10:90 pangolin mixtures and 87.8% of the mixtures with the synthetic wig. We thus met our original objective with both the rat team and individual rats exceeding the 85% detection success. Supporting evidence is provided in section 3.1 and 3.2 of report and in Annex 8.
Activity 2.1. Identification of the most common masking agents through a literature search of seizure data;		The most common masking agents were identified from seizure data (Annex 16) during Year 1 and included: 1) electrical cables, 2) synthetic/plastic hair wigs, 3) new cotton socks, 4) coffee beans, 5) dengu (a native seed used in cooking), 6) cardboard, 7) washing powder, 8) *Delonix regia* (locally referred to as Krismasi or Flame Tree) seeds and 9) seedpod casings, and 10) unshelled, raw peanuts.
Activity 2.2. Procedures to tightly control sample mixture preparation and training procedures are developed; and		Although the photoionization detector (PID) purchased for this purpose failed to register many of the organic materials used, we developed an alternative procedure to control the "relative stinkyness" of the samples by using the mass of each sample substance as a proxy for odour concentration (please refer to Table 1, section 3.1 of report). This technique resulted in unique volumes for each item used for training. These volumes were then used in creating mixtures of varying proportions (refer also to Table 1 and Figure 2).
Activity 2.3. Training on complex scent mixtures, including target scents mixed with commonly used masking agents.		Training on complex scent mixtures, including target scents mixed with commonly used masking agents was fully completed in 2019, after six months of training (three months for each target). Although no measurable indicator was identified for this activity, data from training sessions (Annex 8) fulfils this metric.
Output 3. Feasibility of future operational application is assessed through in-depth psychometric analysis of the rats' sensitivity in detection of target samples, including identification of the minimum concentration among masking agents.	A concentration gradient, which determines the lowest threshold of ratio of one and/or two targets amongst five masking agents of the rats' scenting abilities, is established by month 15.	Testing the rats with a variety of target concentrations (mixture ratios), revealed that the rats could detect the two targets (pangolin and hardwood) even when they comprised 10% or less of a mixture among all 10 masking agents. Notably, the rats even found the targets when they were presented in concentrations lower than what they had ever experienced before (5%). The improvement in detection rate from pre-training baseline to post-training test suggests that the minimum concentration (here, the untrained 5:95) could likely be reduced even further with additional training. These tests were completed after a total of 15 months training (including 9 months of initial training and 6 months of focused training with the target and non-target mixtures). Supporting evidence is provided in section 3.1 and 3.2 of report and in Annex 8.
Activity 3.1. Determining the concentration gradient for rat scent-detection limits for pangolins;		This was accomplished in conjunction with the final test of the rats' ability to detect hidden targets (see above). The lower limit tested contained only 5% pangolin relative to non-target (common masking) items, which many of the rats successfully detected. Notably, the rats had not received explicit training with this lower limit and, given the detection improvement demonstrated for other concentrations (50:50, 25:75, and 10:90), it is likely that this limit could be further reduced with additional training.

		Refer to Figure 4 with additional supporting evidence available in Annex 8.
Activity 3.2. Identification and analysis of psychometric properties of rats' pangolin and hardwood scent detection abilities; and		We identified and analysed the psychometric properties of rat's pangolin and hardwood scent detection abilities after all training was completed in 2019 (see Figure 4 and Annex 8).
Activity 3.3. Assessment of translational relevance to real-life port activity through comparison to seizure data concentrations of illicit material among masking agents.		While the seizure reports did not include volumes of illicit and masking materials seized, media reports of pangolin scale seizures reflect substantial amounts. Smaller seizures usually contain 1 kg or more. Our results show the rats can detect substances as small as 5% of a mixture. Based on this knowledge, the rats could be expected to detect 1 kg of pangolin scales within a 20 kg shipment containing other masking materials. Extrapolating this calculation to the reported seizure of 230 kg of pangolin products in the DRC, the rats could have detected this illicit material hidden within a shipment weighing up to five tons.
Output 4. A system is developed to signal positive detection of pangolin to the rat handlers in a simulated operational environment (i.e. one that simulates conditions for screening containers in a seaport).	All eight rats are able to give their handlers an indication of a positive target scent within 15 months of training, with an obvious three second or more detection behaviour (e.g. scratching).	Not only did all ten rats successfully learn to hold their nose for three seconds over target items during the initial nine months of training, we also developed a variety of deployment systems which each have their own indication response and training timeline that fell well within the 15-month goal. Specifically, 9 rats learned to perform a similar nose-poke indication in response to target odours in our fully automated version of the line cage apparatus within just 3 months; 5 of the 5 rats trained to trigger a microswitch by pulling a small ball attached to their harness learned to reliably perform this action whenever they encountered a target odour within 9 months; 4 of the 4 rats trained to carry a miniature, technology-enabled backpack learned to navigate with this device within a month; and 20 rats learned to interact with the portable chamber device to press a small lever inside to indicate in only about a week of training. Supporting evidence is provided in section 3.1 and 3.2 of report and in Annex 9.
Activity 4.1. Habituation of the rats to a mock port environment;		With the development of alternative deployment systems, this activity was deemed no longer necessary. Because these deployment systems enable the rat to perform its scent detection work without being directly exposed to the external environment, we instead habituated the rats to these containment devices (e.g., the portable chamber). All rats quickly acclimated to this novel environment and showed no interference when subsequent changes to the environment outside of the chamber were made.
Activity 4.2. Assessment of equipment needs to operate in a port environment;		The equipment needed to operate in a port environment was assessed over the course of this project, most notably during workshops held in December 2018 and July 2019 with valuable input from port authorities and stakeholders.
Activity 4.3. Construction of the required equipment;		We have developed equipment to support six potential deployment strategies. The equipment falls into two broad categories: 1) rat-wearable technologies that can

		be used alone or in tandem with 2) transportation and evaluation systems. See section 3.1 for more details.
4.4. Assessment of indication system feasibility in a port environment; and		Our trials suggest the unique indication systems supported by these different apparatuses are feasible for a variety of environments, including working within ports. This is because all rats learned to reliably perform the necessary indication behavior that was easily detectable by a human handler. In the case of the rat backpack, we even discovered that the long-range antennae enabled signal transmission for hundreds of meters, including through the walls of a metal shipping container.
4.5. Determining other variables for successful detection by the rats, such as sample time in the container, container size, etc.		We explored some factors that might influence the rats' successful detection, such as sample time in the container, container size, etc. While these variables will depend on the actual deployment scenario or location, we tested whether the trained rats could detect target smells presented on filter papers while ignoring filter papers soaked in non-target odours. The rats identified samples that were stored for two to four months equally well. Further training and research are needed to support these possibilities and explore what other variables may influence the rats' scent detection once a particular deployment strategy is identified in partnership with port authorities.
Output 5. Women, wherever possible, are included as project staff and are empowered and capacitated at both organisations	5.1 At least three women staff are assigned with project specific responsibilities at APOPO with at least 250 work integrated learning hours logged during project implementation, mentored by the Head of Training & Behavioural Research;	Although APOPO experienced some turn-over during the course of this project (primarily from research technicians who returned to the university to earn advanced graduate degrees, e.g., Haylee Ellis and Kate (Sears)-Webb), three women were always dedicated to this project, including the Head of Research and Innovation, Dr. Cynthia (Cindy) Fast, with day-to-day research activities closely monitored and conducted by Dr. Miriam Schneider and Ms Mariam Juma (see Annexes 12 and 13) APOPO staff logged 4,560 hours on the project to date, with more than 320 learning hours, including mentoring, capacity building, and workshop attendance
	5.2. At least one woman staff member is assigned with project-specific responsibilities at the EWT with at least 250 work integrated learning hours logged during project implementation, mentored by the EWT Wildlife in Trade Programme Manager.	At the EWT, Ashleigh Dore (and before her, Dr. Kelly Marnewick), served as Project Leader and was responsible for the day-to-day coordination of the project and general project management, overseeing the monitoring and evaluation component of the project. The EWT staff logged 625 hours.
Activity 5.1 Identify woman staff willing to participate in the project;		Two women at APOPO served as principle investigators for the project. Dr. Cynthia Fast (the Head of Training & Innovation) and Dr. Miriam Schneider (Senior Researcher). In addition, one female rodent trainer was intimately involved in daily training and care of this project's animals. Additional women research technicians were involved with this project while they were affiliated with APOPO, including Haylee Ellis, Kate (Sears) Webb, and Dian van de Laak.

	Throughout the course of this project, there was always at least one EWT woman staff member directly involved in the project.
Activity 5.2. Assign project specific roles and responsibilities;	All rat training and testing procedures were developed and overseen by APOPO's Head of Training and Innovation. Standard Operating Procedures (SOPs; see Annex 10 for an example) were documented for all stages of the project, including sample preparation and apparatus maintenance. Daily planning of training sessions and monitoring of rat performance was conducted by the designated researcher (most recently, Dr. Miriam Schneider). Actual training sessions with the rat were conducted by APOPO's internally accredited rodent handlers, including Ms. Mariam Juma (see Annex 12).
Activity 5.3. Log time against project activities; and	Actual hours spent on this project, including daily activities, were routinely logged and used in determining that 4,560 total hours were invested.
Activity 5.4. Monitor and evaluate performance and learning for each woman staff member.	APOPO conducts routine evaluation and appraisals of all staff in addition to weekly research team meetings and monthly "data blitz" sessions to monitor and evaluate project progress and identify potential areas for capacity building. Additionally, researchers (research technicians and senior researcher) participate in bi-weekly one-on-one meetings with the Head of Training and Innovation where performance, growth, goals, and objectives are discussed. Finally, rodent handlers/trainers attend weekly staff meetings along with annual refresh training and internal accreditation examinations to monitor performance and learning. The EWT conduct two performance reviews, one in June and the other in December. During these reviews performance against terms of reference are assessed and lodged with HR. For continuous support, weekly meetings are held between the programme manager and the project coordinator, ensuring day to day tasks are on track and addressing any project concerns proactively. Kelly also gave several presentations allowing for valuable learning opportunities.

Annex 3 IWT Contacts

Ref No	IWT039
Project Title	A novel system to detect illegal wildlife in shipping containers
Project Leader Details	
Name	Ashleigh Dore
Role within IWT Project	Wildlife in Trade Programme Manager
Address	
Phone	
Fax/Skype	
Email	
Partner 1	
Name	Dr. Cynthia (Cindy) Fast
Organisation	APOPO
Role within IWT Project	Primary Investigator for rat training and development
Address	
Fax/Skype	
Email	

Annex 4 Onwards – supplementary material (optional but encouraged as evidence of project achievement)

Checklist for submission

	Check
Is the report less than 10MB? If so, please email to IWT-Fund@ltsi.co.uk putting the project number in the subject line.	X
Is your report more than 10MB? If so, please discuss with IWT-Fund@ltsi.co.uk about the best way to deliver the report, putting the project number in the subject line.	
Have you included means of verification? You need not submit every project document, but the main outputs and a selection of the others would strengthen the report.	X
Do you have hard copies of material you want to submit with the report? If so, please make this clear in the covering email and ensure all material is marked with the project number.	-
Have you involved your partners in preparation of the report and named the main contributors	X
Have you completed the Project Expenditure table fully?	-
Do not include claim forms or other communications with this report.	