## *The Success of Post-Release Vervet Monkeys (Chlorocebus pygerythrus hilgerti) in Kenya: An Analysis of Pre-Release Threat-Awareness Tests, Training, and Post-Release Success*

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**The Success of Post-Release Vervet Monkeys (*Chlorocebus pygerythrus hilgerti)* in Kenya:**

**An Analysis of Pre-Release Threat-Awareness Tests, Training, and Post-Release Success**

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## Abstract

We are in the midst of a primate conservation crisis as 75% of the world's primates are in population decline. However, translocation attempts are a promising option to reinforce and reestablish struggling primate populations. While factors that often result in translocation failures have been identified in previous research, there is still a poor understanding of what aspects of rehabilitation creates or predicts repeatable success post-release. This thesis is an analysis of Andrea Donaldson's original case study on the rehabilitation release of vervet monkeys, *Chlorocebus pygerythrus hilgerti,* in Diani, Kenya. I aimed to evaluate the efficacy of pre-release threat-awareness tests and electrical wire training by investigating the behavioural responses of the vervet monkeys, how their individual traits may influence their response, the influence of social learning, and the predictive nature of their response to these tests and training on their post-release survival and success. Before release, the vervets underwent awareness tests for the predicted threats found in their anticipated habitat, which included baboons, dogs, humans, and snakes, and they were trained to avoid electrical wires. The responses of each vervet were recorded and statistically analysed. Results indicated that vervets showed inconsistent threat response improvement during rehabilitation; however, electrical wire training was effective. While no statistical correlation was found between a vervet's background and their response score, their survival rates upon release into the wild were comparable to those of a wild control group. Additionally, observing another individual receiving a shock during pre-release training had no subsequent effect on the number of shocks administered to the observer during electrical exposures. These findings affirmed the efficacy of these methods of rehabilitation pre-release and indicated that future research can further perfect the process of threat training and testing to promote post-release success.

# 1 Introduction

## 1.1 Background

Nonhuman primates are humans' closest biological relative which makes them a focus of many biological studies. As anthropogenic factors continue to put pressure on wild species, a conservation crisis has been identified in primatology (Torres-Romero *et al.* 2023). About 75% of the world's primate species are experiencing population decline, of which there are over 500 non-human species worldwide, and about 60% of species are at risk of extinction, creating a race to identify the current issues in conservation efforts and create solutions to stop this conservation crisis (Estrada *et al*. 2017). Conservationists are turning to translocations to help re-establish declining populations and to relocate primates in peril. The term translocation is broadly defined as the movement of an individual or group from point A to point B and features various sub-categories tailored to the nature of each situation (IUCN 1987). The sub-categories within translocation serve to define both the purpose and method of release for the target species. Specifically, conservation translocations encompass situations where movement of a species is necessary for the survival of the species, and non-conservation translocations describe instances where conservation is not the primary focus of the release attempt (IUCN/SSC 2013). These two sub-categories break down even further into groups based on various approaches and goals (see Table 1) but will always feature the release of an animal (IUCN/SSC 2013).

| | | | |
|---|---|---|---|
| **Translocation** | **The human-mediated movement of living organisms from one area, with release in another** | | |
| | **Non-conservation translocation** | The intentional movement and release of a living organism where the primary objective is not a conservation benefit. IUCN recognise these types of translocations may have conservation benefits, but that conservation benefit is not the primary objective for translocation | |
| | | **Rehabilitation release** | The release of individuals for the sake of their welfare, or for rehabilitation from captivity |
| | | **Commercial or recreational** | The augmentation of a population for the purposes of recreational or commercial off take |
| | | **Mitigation translocation** | The removal of organisms from habitat due to be lost through anthropogenic land use change and release at an alternative site. The release site will dictate the nature of the mitigation measure; population restoration or conservation introduction |
| | | **Removal for intensive protection** | The removal of organisms from their natural environment into condition of intensive protection, as provided by zoological and botanic gardens and other dedicated facilities |
| | | **Least risk, least regret translocation** | The translocation of species that are neither natural scarce nor declining, nor with high probabilities of extinction. These often occur as partnerships between local communities and |

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|---|---|---|---|---|
| | | | | conservation professionals, in which the principal motivation is the restoration of a component of local cultural heritage |
| **Translocation** | | | | **The human-mediated movement of living organisms from one area, with release in another** |
| | **Conservation translocation** | | | The intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem function or processes |
| | | **Population restoration** | | Any conservation translocation to within indigenous range |
| | | | **Reinforcement** | The intentional movement and release of an organism into an existing population of conspecifics |
| | | | **Reintroduction** | The intentional movement and release of an organism inside its indigenous range from which it has disappeared |
| | | **Conservation introduction** | | The intentional movement and release of an organism outside its indigenous range |
| | | | **Assisted Colonisation** | The intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species |

| | | |
|---|---|---|
| | **Ecological replacement** | The intentional movement and release of an organism outside its indigenous range to perform a specific ecological function |

**Table 1** Definitions of intentional translocations and the various approaches within the translocation spectrum, as direct citations from IUCN/SSC/RSG publication (with permission of Donaldson, 2017

Despite being a popular topic in conservation currently (Mittermeier *et al*. 2024), translocations have been used for decades without adequate recognition (Griffith 1989). While data are scarce, translocations were conducted as early as the 1970s in Indonesia to help the declining populations of orangutans (Warren *et al.* 2002). With the impacts of climate change unfolding before us, more populations of species will face displacements and an increase in threats to their survival (McAdam 2010), emphasising the need for feasible and successful methods to protect these vulnerable individuals. Conservation biologists have examined past translocation attempts to identify what factors influenced successful and failed releases (Beck 2016). Accordingly, a key aspect of successful translocations is the ability of released individuals to identify and react appropriately to various threats posed by their natural habitat (IUCN/SSC 2013); therefore, there is a need for adequate pre-release methods to ensure that the released animals respond appropriately.

### 1.2 Pre-Release Tests and Training

Following extended periods of captivity, individuals may acquire what is called prey naivety, classified as the loss of appropriate reaction to predator species and threats (Banks *et al*. 2018). Especially for those who were born in captivity or removed from the wild at an extremely young age, learning essential life skills is almost impossible (Baker 2002). This naivety can also be observed in wild species that have not been exposed to threats from a predator in their natural environment (Banks and Dickman 2007). While time in captivity is aimed at keeping the target species out of any danger, especially that of predators, this can become a problem when individuals face translocation. Each conservation translocation needs to be tailored to its target species and their individual backgrounds in captivity, with a goal to promote self-sustaining populations of animals in the wild and encourage species viability. Similarly, non-conservation translocations function in the interest of individual success and livelihood, not necessarily species conservation, although it may result in unintentional conservation benefits (IUCN/SSC 2013). Thus, predator and threat awareness training is an essential aspect of pre-release preparation (Baker 2002). Early studies of translocated *Leontopithecus rosalia*, or golden lion tamarins, show that the second highest cause of loss (classified as a death or removal from study), after human theft, was death by mammalian or avian predators. In that study, about 8% of all deaths were related to inappropriate responses to predators, indicating the importance of extensive training and tests before release (Beck *et al.* 1991). As explained by Baker (2002), ensuring that individuals can recognise and react appropriately to threats, especially predators, is directly related to the success of translocations.

After the IUCN and Natural Resources Species Survival Commission Reintroduction Specialist Group was established in the 1980s, it became evident that any naïve species would need to undergo training pre-release to elevate their chance of survival once they were released (IUCN 1987). Following their recommendations, translocations that result in more positive outcomes regarding survival and reproduction have become more common (Beck *et al*. 1991, Cade and Temple 1995, Griffith *et al*. 1989, Beck *et al*.1994, Kierulff *et al*. 2012, Ruiz-Miranda *et al*. 2010, Tutin *et al*. 2008), and it appears that threat awareness has an important role in the outcomes, highlighting the need for further research and species-specific approaches to releases (Cheyne *et al.* 2012). Rehabilitation releases are often assessed on a group basis where the entire group must average a specific score in threat awareness tests, neglecting research into individual progress or regression (Guy *et al*. 2013).

### 1.3 Successful Translocations

Although success can be measured in several ways depending on the purpose of the release, two primate translocation studies are widely accepted as successful. After 30 years since the release of the original primate group, the golden lion tamarin (GLT) conservation program has proven the importance of translocations and how they can be used to combat population decline (Kierulff *et al*. 2012). This species had nearly gone extinct in 1983, but in conjunction with multiple zoos, a group of captive individuals were reintroduced to Poço das Antas in Brazil through a conservation translocation, specifically with the aim of population restoration. The reintroduction of GLTs continued up until 2000, and in 2011, the IUCN no longer categorised this species as critically endangered (Kierulff *et al*. 2012). Conservation translocation was essential in this situation because the worldwide population of GLTs was teetering on extinction, requiring efforts to be made on behalf of the entire species (Ballou *et al.* 2010). In the case of the GLTs, the translocation was classified as a conservation-based reintroduction, unlike the goal of this study, which is a rehabilitation release. However, like the focus of this thesis, Ruiz-Miranda *et al.* (2010) also released wild-born captive GLTs in 2005, which contributed to the current thriving population of wild tamarins within privately owned forests and provided insight into successful pre-release methods of rehabilitated primates.

A rehabilitation-release attempt that is considered successful is that of the HELP sanctuary. This study translocated a captive group of 20 wild-born orphaned chimpanzees into the Republic of Congo. The orphans were assumed to have been originally born in Central Africa but were confiscated from illegal activities like the pet trade. The mortality rate for this released group was 10%, and 14 of the 20 original released chimpanzees were often observed upon publication of the study, 3 years post-release (Tutin *et al*. 2008). These successful translocation attempts differ in many ways from my proposed research, but they can help identify why those attempts were successful and what factors may have played the biggest role. Specifically, the release of wild-born captive chimpanzees (Tutin *et al*. 2008) is most applicable to this research as I will be considering the backgrounds of rehabilitated and released vervets in relation to pre-release rehabilitation and post-release outcomes.

## 1.4 Andrea Donaldson's 2017 Research

In 2017, Andrea Donaldson published her research on a rehabilitation-release translocation case study on *Cercopithecus pygerythrus hilgerti,* known as vervet monkeys, in Kenya. Data collection on the release vervet monkeys was conducted over a pre and post release monitoring time frame of 20 months. Donaldson also collected and used 24 months of observational data on two habituated control groups to inform release site selection and as comparators for release group success. The findings of the study were that the release was successful in relation to survivorship, activity budgets, and general feeding ecology being compared to ranges set by the control groups. Donaldson indicates that the continuation of analysis on rehabilitation release within Diani would be of interest for future research, specifically life-skill training, predator and electricity awareness training, and post-release data (Donaldson 2017).

### 1.4.1 Study Species

The study group of *Cercopithecus pygerythrus hilgerti* were all wild-born monkeys that required a period of treatment and rehabilitation in captivity, following various human/wildlife interactions. Most notably, individuals were orphaned as young infants, kept as pets or confiscated from poachers. Due to their conservation status of Least Concern (Butynski, T.M. & De Jong, Y.A. 2022), the classification of translocation for this group was a non-conservation translocation, more specifically, rehabilitation release (IUCN/SSC 2013), with the focus being the welfare of the individual vervets. I will use the data from threat awareness exposures, that the vervet monkeys underwent, as these may present insight into the differing levels of threat naivety seen in rehabilitation participants and their ability to learn appropriate reactions to biotic and abiotic threats.

The vervets were rescued from different backgrounds, but were all assumed to be naïve to natural threats and spent anywhere from 3 to 39 months in captivity and were not released until deemed appropriate. In the case of Colobus Conservation in Diani, Kenya, the Release group was not approved for release until the group showcased average appropriate behaviour across all individuals to both predators and anthropogenic threats prevalent in the release environment. For the purpose of this research, baboon, dog, human, snake, and electrical wire exposures were reviewed and statistically analysed per individual.

The individuals from this study were *Cercopithecus pygerythrus hilgerti*, commonly known as the vervet monkey. The Release group consisted of 12 vervets including 5 males and 7 females who ranged in age from infant to adult upon release. The rehabilitation threat training and tests were conducted during the three months prior to release on May 27th, 2012. In addition to the Release group, there were two control groups: the University Group and Hotel Group. The University control group consisted of 23 individuals, 8 adult and sub-adult males, 7 adult and sub-adult females and 8 juveniles who were identified by their physical features, such as scars, size, and coat colour. Similarly, the Hotel control group consisted of 19 individuals, 4 adult and sub-adult males and 7 adult and sub-adult females, 5 juveniles and 3 infants and were identified in the same way.

### 1.4.2 Release Site

The release site of Diani, found within the Kwale District along the shore of Kenya (see Figures 1 and 2), was selected after numerous factors were assessed in Andrea Donaldson's original research. Critical factors to consider prior to release, included habitat composition, food availability, and the potential impact of released individuals on the ecosystem (Cheyne 2006). It was determined that the release site in Diani would be capable of supporting 12 additional released vervets and had a lower human density than the surrounding habitats used by local wild vervet groups. The key threats identified in this release site were baboons, dogs, humans, snakes, and electrical wires.

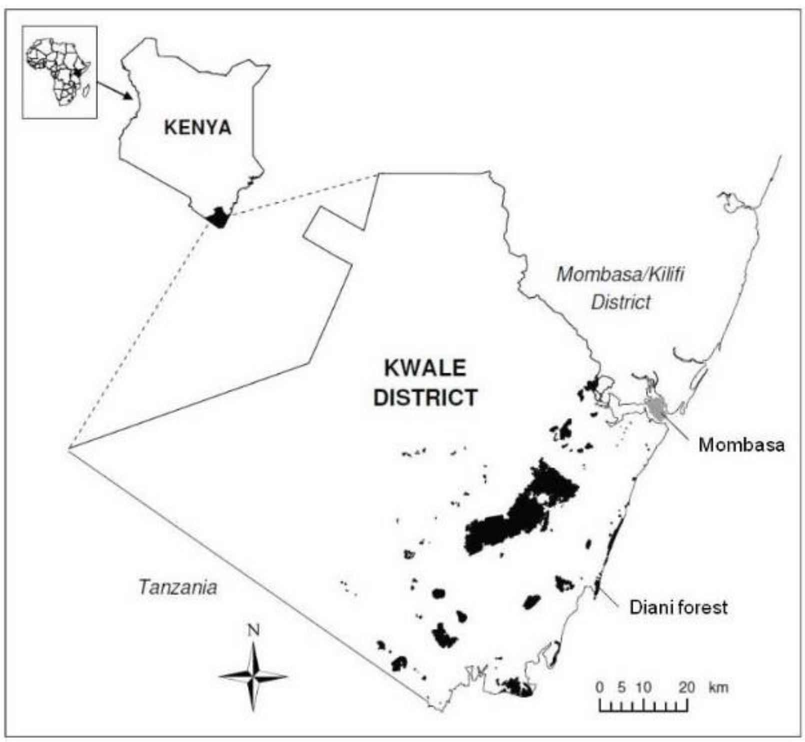


**Figure 1** The distribution of coastal forest fragments in Kwale County, Kenya (with permission of Donaldson, 2017, who edited Anderson et al, 2007).


**Figure 2** A land map and an aerial photograph of the greater Diani area. Area outlined in yellow shows Colobus Conservation area of operation. Protected forests (Kayas) and Colobus Conservation Centre are labelled. Land map image 2006 CNES/Astrium Data SIO, NOAA, U.S., Navy, NGA, GEBCO. Aerial photography ©2016 DigitalGlobbe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation. (with permission of Donaldson, 2017)

All vervet groups were located in areas that were semi-urbanised and experienced human disturbances; however, each group also had access to large areas of forests (see Figure 3). The University group's habitat surrounded the Nairobi University field stations and a small hotel complex. The Hotel group was located near two large hotels and residential areas.

**Figure 3** Map of 18 known locations of vervet monkey groups in Diani. The yellow line delineates the census survey area. The red circle indicates Hotel group, blue circle indicates University group, and yellow circles indicate all other recorded vervet groups. Scale 1:100,000, ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation. (with permission of Donaldson, 2017)

### 1.4.3 Donaldson's Results

While reproduction is a useful and common measure of success in translocation cases (Beck *et al.* 1991; Cade and Temple 1995), rehabilitation releases pose a challenge as the aim is to translocate those individuals to improve their welfare rather than to conserve the species. An appropriate measure of post-release success may be the percentage of survivorship post-release. In addition to looking at births, Beck *et al.* (1991) assessed the number of surviving golden lion tamarins 6 years post-release. Doing so allowed for further analysis of the efficacy of release techniques on an individual and group level, focusing on the immediate success of the individuals. In this study, 4 out of the 12 individuals died by 18 months post-release, resulting in a 66.6% survival rate in the Release group (Donaldson 2017).

## 1.5 Research Questions/Hypothesis/Predictions

Donaldson's study showed that her release was successful because the biological and behavioural measures fell within the expected ranges, such as survival rates, activity budgets, feeding ecology, and day journey lengths. What we don't know is if current rehabilitation methods adequately prepare vervet monkeys for life in the wild upon release and where we may want to see improvements. I investigated this by analysing the responses of rescued vervets to specific threat-awareness tests/training in rehabilitation, the role of their individual experiences and social learning, and the correlation between their responses to tests/training and post-release success. My research is broken down into three key research questions and associated hypotheses and predictions as outlined in the subsequent sections.

### 1.5.1 Research Question 1: The Response of Captive Vervet Monkeys to Rehabilitation Tests and Training

To avoid the continuation of threat naivety in the vervet individuals, the release vervets in Donaldson's study underwent threat awareness tests where responses to the presented threats were recorded. As continued awareness training can create an appropriate conditioned response (Mirza and Chivers 2000), I hypothesise that an individual will learn to react appropriately to a threat over the course of the awareness testing for that threat. I will assess their learning based on a test-by-test basis because vervet threat calls are highly specialised and elicit a specific reaction based on the observed threat, meaning that an appropriate response to one threat may not be the same for another (Seyfarth and Cheney 2003). I predict that the individual's appropriateness of response scores in each isolated test type (baboon, dog, human, and snake) will improve with each exposure trial. Additionally, with each exposure to electrical wires in electricity awareness training, the number of shocks will decrease per individual because the presentation of the threat is paired with the negative stimulus of a shock, resulting in a learned and conditioned response (Mirza and Chivers 2000).

Social learning is an important part of threat training and occurs through observing how other, typically older (van de Waal *et al.* 2010; van de Waal *et al.* 2013; Whiten and van de Waal 2018) individuals interact and respond to the world around them. Social learning can enable transmission of valuable information between individuals about resource or habitat locations, migration routes, tool-use, and threat response, which is essential information that can drastically impact the success of translocations (Brakes *et al.* 2025). Observational learning, a type of social learning, can be a powerful tool in rehabilitation because individuals can learn threat responses without ever being in danger themselves (Harrison 2024), as the intense emotional reaction of an experienced demonstrator is sufficient to condition a fear response in the observer (Mineka and Cook 1993). Studies have shown that naïve prey become more wary of predators after being exposed to a demonstrator individual who responded fearfully to the threat than those who were not, indicating a level of social learning in these trainings (Mineka and Cook 1993; Shier and Owings 2007). Observational learning can be applied to rehabilitation in a number of ways, for example, showcasing the reaction to threat via a knowledgeable demonstrator so that the naïve individuals can observe a suitable response to a presented predator or threat. Additionally, observing the consequences of another naïve primate reacting inappropriately to a threat allows the observer to identify the risks of an inadequate response. Given these findings, I hypothesise that individuals who observe negative reactions to threats by others will learn to be afraid of the threat (at least partially) through social learning. It is only appropriate to test this hypothesis with the electricity wire exposure training because the predator-awareness trials do not feature records of who observed whom responding to the threat, and it's the only training that uses a negative stimulus to reinforce appropriate responses. I predict that if a naïve vervet monkey 'observes' another individual receiving a shock, they will experience fewer shocks than naïve individuals who did not observe a peer receiving a shock.

### 1.5.2 Research Question 2: Individual Variability and Its Impact on Rehabilitation Test and Training Success

One way to analyse rehabilitation releases on a smaller scale is to assess the effect of individual differences on threat awareness and training outcomes and post-release success. The capabilities of an animal to react to predators rely on the intersection of multiple factors, those being characteristics obtained through natural selection over generations and the "accumulation of experiences during individual lifetimes" (Griffin *et al.* 2001, pg. 1319), establishing the importance of pre-release exposure to threats. Accordingly, I hypothesise that an individual's developmental stage would influence threat awareness reactions during rehabilitation. Specifically, I predicted that across all threat awareness tests, threat awareness scores upon initial presentation (encounter 1) will be higher on average for the adult/sub-adult group compared to the infant/juvenile individuals. Additionally, I predicted that as developmental age increases, there will be a decrease in the average amount of shocks upon initial exposure to electrical wires.

Due to the Release vervets all coming from diverse backgrounds, another way I explored the impact of individual differences is by examining the patterns seen in individuals who experienced some level of captivity, to our knowledge, prior to being rehabilitated at Colobus Conservation. Extensive research into the physical and psychological effects of captivity has shown that the lack of a natural environment can negatively impact the well-being of animals and result in the loss of vital threat responses (Mallapur and Choudhury 2003; Lutz and Novak 2005; Banks et al. 2018). Understanding such led me to hypothesise that individuals who experienced captivity previously would show a higher frequency of inappropriate behaviours in threat tests because, in previous studies, it has been noted that vervet alarm calls and corresponding reactions improve with age and experience in the wild (Seyfarth *et al.* 1980b). In this study, I predicted that individuals who have previous experience in captivity will start with lower scores in baboon, dog, human and snake threat exposures than individuals who have never experienced captivity. Regarding the electricity wire training, I predicted that individuals who come from a captive background would have a higher frequency of touches of the electrical wire during each trial and more shocks than non-captivity-experienced vervets.

It should be noted that there may be an interaction between these two hypotheses (i.e. Developmental stage at the start of training/tests, and experience of captivity prior to living at Colobus Conservation), but given the small sample size, it is unlikely to be possible to quantitatively examine the interaction.

### 1.5.3 Research Question 3: The Relationship Between Pre-Release Performance and Post-Release Behavioural Outcomes

Using survivorship rates post-release as a measure of success and given literature emphasising the importance of threat awareness for post-release survival (Baker 2002), I hypothesised that pre-release threat awareness tests may predict, and electrical wire training influence, post-release behaviour and success. Particularly, I predicted that the Release group of vervets will exhibit a similar rate of encounters with threats per month during the comparable time period, May 28th, 2012 – November 30th, 2013, as the two control groups if the Release group presents appropriate response scores prior to release. Additionally, I predicted that the Release group will demonstrate a similar death rate per 100 days as the two control groups and will have similar causes of death to the control group.

The research questions and associated hypotheses and predictions are summarised in Table 2.

| Research Question 1 | How do captive vervet monkeys respond to threat awareness testing / training in rehabilitation? | | |
|---|---|---|---|
| | **Hypothesis 1** | An individual will learn to react appropriately to a threat over the course of awareness testing or training for that threat. | |
| | | **Prediction A** | Individual scores for each test type (baboon, dog, human, and snake) will improve with exposure. |
| | | **Prediction B** | With each exposure to electrical wire, the number of shocks will decrease per individual. |
| | **Hypothesis 2** | Individuals who observe negative reactions to threats by others will learn to be afraid of the threat (at least partially) through social learning. | |
| | | **Prediction A** | If a vervet monkey observes another individual receiving a shock, they will experience fewer shocks than individuals who do not observe a peer receiving a shock. |
| **Research Question 2** | How do individual differences among vervet monkeys affect their response to threat awareness testing / training in rehabilitation? | | |
| | **Hypothesis 1** | An individual's developmental age will influence threat awareness reactions during rehabilitation. | |
| | | **Prediction A** | Across all threat awareness tests, threat awareness scores upon initial presentation (encounter 1) will be higher on average for the adult/sub-adult group compared to the infant/juvenile individuals. |
| | | **Prediction B** | As developmental age increases, there will be a decrease in the number of shocks upon initial exposure to electrical wires. |
| | **Hypothesis 2** | Individuals who experienced captivity previously will show a higher frequency of inappropriate behaviours in threat tests and training. | |
| | | **Prediction A** | Individuals who have previous experience in captivity will start with lower scores in baboon, dog, human, and snake awareness trials than individuals who have never experienced captivity. |
| | | **Prediction B** | Individuals who come from a captive background will have a higher frequency of touches of the electrical wire than non-captivity-experienced vervets during their initial exposure in training. |

**Table 2.** Outline of research questions, hypotheses, and predictions which are discussed in this thesis.

| | | | |
|---|---|---|---|
| **Research Question 3** | How does pre-release training and threat awareness testing influence and/or predict post-release behaviour and success? | | |
| | **Hypothesis 1** | The outcomes of pre-release awareness tests / training may predict post-release behaviour and success. | |
| | | **Prediction A** | The Release group of vervets will exhibit a similar rate of encounters with threats per month as the two control groups if the Release group presents appropriate response scores prior to release. |
| | | **Prediction B** | The Release group will demonstrate a similar death rate per 100 days as the two control groups. |
| | | **Prediction C** | The Release group will have similar causes of death to the control group. |

**Table 2 Continued.** Outline of research questions, hypotheses, and predictions which are discussed in this thesis.

# 2 Methods

## 2.1 Donaldson’s 2017 Research Methods

Once environmental threats were determined in the planned release site, awareness testing and training for applicable threats were designed so that individuals could be scored based on the appropriateness of their response. In Donaldson’s original research, a score of 3 or above in the threat awareness testing in relation to baboons, dogs, humans, and snakes was considered a satisfactory score on an individual basis, indicating that the vervet obtaining those scores was exhibiting appropriate reactions to the presented threat. Appropriate response to electrical wire training is complete avoidance of the cable, which is the ideal outcome (Donaldson 2017). Specific details of threat awareness tests and training are given below.

### 2.1.1 Baboon Awareness Testing

Colobus Conservation identified five local yellow baboon, *Papio cynocephalus*, groups in Diani who may act as both competitors and predators to released individuals (Donaldson 2017). To assess the threat response of the Release group, the responses of these individuals to live baboons entering and exiting the Colobus Conservation rehabilitation grounds and approaching their enclosure were recorded. Seven instances, categorised as “ad hoc” events, occurred during the testing timeframe, where all vervets were observed by trained researchers who scored their reactions on a scale of 0-5 (see Table 3). In addition to being assigned a score, any behaviour of note was also recorded per individual. The baboon awareness events occurred on April 3rd, 5th, 9th, 12th, 17th, 18th, 24th, and May 1st, 2012. The baboons featured in the exposures varied in size, sex, age, and number.

| Test Score | Associated Response | Threat-Specific Positioning |
|---|---|---|
| 0 | Predator seen and individual approaches and attempts to initiate contact with predator | N/A |
| 1 | No response (continuation of current behaviour / change to another non-predation related behaviour) | N/A |
| 2 | Curiosity towards predator, including visual attentiveness | N/A |
| 3 | Alarm calling and/or appropriate positioning in response to other's doing so | N/A |
| 4 | Alarm calling and/or appropriate positioning in direct response to the predator | Baboon – move away from threat (ideally up a tree), Dog – climb up a tree, Human - move away from the threat (ideally up a tree), Snake – Move away or up a tree, perching on back legs, and looking at the threat. |
| 5 | The individual initiates alarm call and moves to appropriate positioning | Baboon – move away from threat (ideally up a tree), Dog – climb up a tree, Human - move away from the threat (ideally up a tree), Snake – move away or up a tree, perching on back legs, and looking at the threat. |

**Table 3** Test scores and the corresponding behavioural response of the subject animals when presented with four different threats

### 2.1.2 Dog Awareness Testing

Another significant predator of Diani vervet monkeys is dogs, both feral and pets. Both small and large dogs can attack vervets and other monkeys, so two testing instances were designed to simulate the presence of different-sized dogs. The test trials consisted of a researcher walking a dog on a lead around the perimeter of the vervet's enclosure without coming into direct contact with the captive individuals. The vervets were observed and scored on a scale of 0-5 based on expected responses (see Table 3). On April 6th, a large dog was presented, and on May 17th, testing featured a smaller dog.

### 2.1.3 Human Awareness Testing

The final biotic threat tested in Donaldson's study was humans. The presence of humans creates a myriad of different threats to vervet monkeys, most commonly the threat of being captured, attacked, and/or killed (Chapman *et al.* 2016). A large concern during this research was the vervet's habituation to the presence of humans, specifically an association between humans and food. If the vervets become habituated to the presence of humans, they may begin to approach humans upon release, which can result in human-wildlife conflicts. Throughout rehabilitation, the vervet monkeys had little to no contact with humans while in their enclosure. If a researcher or conservation worker was required to enter the enclosure during feeding or testing set-up, all vervets were kept in a separate section of the enclosure to avoid any human contact. The vervets experienced three human awareness testing trials where humans of different genders, stature, and ethnic origins were presented to the Release group in an anti-cage, the two-door system into the enclosure to prevent escapes and unintentional human interaction. Vervet reactions were recorded on a level of 0-5 (see Table 3). The three human testing events occurred on May 16th (Large Male, Familiar), May 17th (Medium Female, Admin Staff), and May 23rd (Small Female, Unfamiliar).

### 2.1.4 Snake Awareness Testing

Over 50 different species of snakes are found in Kenya, and despite only a small fraction of those being venomous, they are still one of the vervet's most prevalent predators (Animalia 2025). Testing involved a wooden snake model attached to a long piece of fishing wire, which was dragged across the floor of the vervet's enclosure from a hiding spot. There were 2 such planned trials where a non-living model was used to test the responses of the individuals (May 8th, 16th, 2012) and one unplanned trial where a live snake was observed 5-10 metres outside the enclosure by some of the vervets (April 26th, 2012). All snake tests were scored on a scale of 0-5 (see Table 3).

### 2.1.5 Electrical Wire Training

Electrocution is the second largest cause of death in Diani primates (Donaldson 2017), indicating that naïve individuals must learn the risk of their presence. To reinforce the fear of electrical wires, the vervets in this study were exposed to carefully constructed electrical wiring. The voltage of these wires was set to 3.5KV and was pulsing, avoiding the potential, as in the wild, for an individual to grasp the wire and become unable to let go, leading to fatal electrocution. The electrical cables were a replica of those seen in the release site and, as in the wild, required vervets to touch two wires to receive a shock. The vervets were exposed to the electrical wires on May 18th (duration of 5.75 hours), May 19th (5.75 hours) and May 23rd (2.25 hours). During each training session, every individual's interaction with the electrical wires was recorded - touches with shocks (touching both wires with anybody part, which produced a shock), touches without shocks (grabbing one of two wires with a hand, which did not complete the circuit and produce a shock).

### 2.1.6 The Release

One week before release, the Release group were fitted with radio-collars to closely monitor the welfare and activities of the individuals. After release, on May 27th, 2012, post-release monitoring began on May 28$^{th}$, 2012, and was conducted for 18 months until November 2013. Instantaneous focal observations began with daily followings of the group from dawn till dusk, then were reduced over time. At 15 weeks post-release, the individuals were monitored for one full day during the week; at 18 months post-release, monitoring ceased. Observational data on the control groups were collected over 24 months from December 2011 to November 2013. Collection of these data occurred during three consecutive research periods per week per control group. Data were collected on ranging behaviour, activity budgets, diet, human food access, and wildlife interactions.

## 2.2 Data Analysis

The vervet threat-awareness tests, captive background, developmental stage, post-release threat encounter, and survival rate data collected from Donaldson's original thesis were thoroughly cleaned to standardize the data and check for errors, input digitally into excel, and statistically analysed using the coding platform R-Studio.

### 2.2.1 Research Question One: How do captive vervet monkeys respond to tests and training in rehabilitation?

To assess whether response scores differed significantly across successive baboon exposure events, pairwise Wilcoxon rank-sum tests were conducted. This non-parametric approach was selected because response scores were not normally distributed and because not all individuals were present for each ad hoc exposure, resulting in unequal sample sizes across exposure events. Bonferroni-adjusted p-values were applied to account for multiple comparisons, and effect sizes were calculated to support interpretation of biological relevance. Initially, Friedman tests were conducted for the dog, human, and snake exposures to assess whether scores differed significantly across exposure sessions. This non-parametric repeated-measures approach was selected because response scores were not normally distributed and involved repeated observations of the same individuals across exposures. When significant effects were found, pairwise Wilcoxon signed-rank tests were then performed to identify specific differences between exposure sessions. Z-statistics were calculated to indicate both the magnitude and direction of changes in scores as exposure number increased. Similarly, a Friedman Chi-Square Test was conducted on the electrical wire training, which was performed pre-release, to determine whether there was a significant relationship between the mean number of shocks received and exposure number. To assess whether observation of others receiving shocks was influential on the number of subsequent shocks received, "observing" another individual was categorised by the orientation of an individual's head toward the individual of interest. Locations that resulted in obstructed views were taken into account, and any instances where observation was doubted were not recorded as such. Statistical analysis consisted of Spearman's rank correlation to assess the relationship between observing a group member receiving a shock, a yes or no variable, and the total number of subsequent shocks an individual received, as this approach is appropriate for non-normally distributed and ordinal or binary data.

#### 2.2.2 Research Question Two: How do individual differences among vervet monkeys affect their tests and training in rehabilitation?

To further understand how individual difference (see Table 4) play a role in initial response to threats during awareness exposures, Wilcoxon-Rank Sum tests were employed to compare the median threat awareness scores and shocks received from the first exposure to a threat between the two developmental groups. Analysis was restricted to the first exposure to minimise the influence of learning, habituation, and prior experience on subsequent responses. This non-parametric approach was selected because response scores and shock counts were not normally distributed, and sample sizes differed between groups. Additionally, the two developmental groups were independent, making the Wilcoxon Rank-Sum test appropriate for between-group comparisons. The same approach was applied to compare median threat awareness scores and shocks received between individuals with and without a known history of captivity, in order to assess whether prior captive experience influenced initial behavioural responses.

| Vervet ID | Sex | Developmental Stage on Arrival at CC* | Developmental Stage Upon Release | Time in Pre-Release Group (Months) | Presence of Previous Captivity Background | Background* | Fate (Nov 2013) | Fate (May 2016) |
|---|---|---|---|---|---|---|---|---|
| BA | M | Infant | Sub-Adult | 35 | No | Orphan | Alive | Alive |
| DI | F | Infant | Sub-Adult | 22 | Yes | Captured by poachers | Died 14/10/2013 WVC - Pregnant | N/A |
| EM | F | Infant | Juvenile | 22 | No | Orphan | Alive | Missing – May 2014 |
| EY | M | Infant | Sub-Adult | 35 | No | Pet | Alive | Missing April 2015 |
| FA | F | Sub-Adult | Adult | 19 | Yes | Pet | Alive | Alive |
| HJ | M | Unknown | Adult | 3 | Yes | Release from CC in 2009, lived on-site as a lone male | Died 06/01/2013 HWI | N/A |

**Table 4.** Table of Vervet Individual Differences**.** Backgrounds on each vervet are based on information upon being brought to Colobus Conservation. * Based on estimated age on arrival and known circumstances of the individual before arrival, F = Female, M = Male, HWI - Human wildlife interaction, WVC - Wildlife vehicle collision (Reproduced from Donaldson 2017, pg. 125).

| Vervet ID | Sex | Developmental Stage on Arrival at CC* | Developmental Stage Upon Release | Time in Pre-Release Group (Months) | Presence of Previous Captivity Background | Background* | Fate (Nov 2013) | Fate (May 2016) |
|---|---|---|---|---|---|---|---|---|
| HO | F | Juvenile | Juvenile | 9 | No | Suspected infanticide victim | Alive | Alive |
| KT | F | Juvenile | Adult | 31 | Yes | Pet | Alive | Alive |
| ML | F | Infant | Juvenile | 6 | Yes | Pet | Died 26/04/2013 Head injury | N/A |
| MM | M | Infant | Infant | 6 | No | Orphan | Died 05/06/2012 Natural causes | N/A |
| RA | F | Juvenile | Juvenile | 8 | No | Head injury via HWI | Alive | Alive |
| ST | M | Infant | Sub-Adult | 35 | No | Captured by poachers | Alive | Died 03/11/2014 Necropsy inconclusive |

**Table 4 Continued.** Table of Vervet Individual Differences**.** Backgrounds on each vervet are based on information upon being brought to Colobus Conservation.

* Based on estimated age on arrival and known circumstances of the individual before arrival, F = Female, M = Male, HWI - Human wildlife interaction, WVC - Wildlife vehicle collision (Reproduced from Donaldson 2017, pg. 125).

### 2.2.3 Research Question Three: How does pre-release training and testing influence and/or predict post-release behaviour and success?

To compare the encounter rates of threats (baboons, dogs, and snakes) across groups, a Kruskal-Wallis statistical test was conducted. This non-parametric approach was selected due to non-normality in encounter rate distributions and unequal sample sizes among groups. Human interactions were not observed in the control groups, so comparative analysis was not possible for this threat type. The analysis included three groups: the Release group (N=12), the Hotel group (N=32), and the University group (N=33). Data were restricted to encounters observed during a comparable 18-month post-release time frame (May 28, 2012 – November 30, 2013) to ensure consistency in observation effort and exposure duration. I used the survival rate as a measure of success for these welfare-based releases because it magnifies each individual's success and how pre-release factors may have affected the survival rate of the individuals. Additionally, I calculated the mean number of deaths per 100 calendar days in the Release group and compared these rates to the comparable period for the original cohort of the control groups to investigate the survival rate post-release. Individuals born after 28 May 2012 were excluded from this analysis to ensure comparable exposure periods. Differences in death rates were analysed using a Poisson regression model, which is appropriate for modelling count data representing rare events occurring over time. This approach accounts for variation in observation periods and enables direct comparison of mortality rates between groups. Finally, a descriptive analysis of the fates of individuals in each of the three groups was undertaken to investigate the key causes of deaths and their percentages in each group during the comparable time frame of 552 days (May $28^{th}$, 2012 – November $30^{th}$, 2013). Any deaths that were not a result of the threats tested in my study were categorised under “other”; these were an inconclusive autopsy and an individual who succumbed to natural causes.

# 3 Results & Discussion by Research Question

This section is dedicated to presenting the statistical results derived from the predictions of each research question. Immediately following the results, the study's findings will be discussed for each question individually. All these points will then be consolidated and fully explored in the General Discussion section that follows.

## 3.1 Research Question One: How do captive vervet monkeys respond to tests and training in rehabilitation?

### 3.1.1 Results

**Hypothesis 1 –** An individual will learn to react appropriately to a threat over the course of awareness testing or training for that threat.

**Prediction A:** Individual scores for each test type (baboon, dog, human, and snake) will improve with exposure.

**Baboons.** A series of pairwise Wilcoxon Rank-Sum tests of baboon test scores indicated a moderate effect size between exposure 1 and 7 ($R = 0.302$). The results indicated no statistically significant difference in test scores between any of the exposure pairs (all adjusted $p = 1.0$). The Z-statistics for these pairwise comparisons ranged from 0 to 1.325 (Table 4), with all corresponding Bonferroni-adjusted p-values being 1.0.

The median scores across the 7 baboon exposures ranged from 2 to 4, and a change from a median of 3 on the first exposure to 4 on the final encounter (Figure 4).

| Baboon Training Pairwise Wilcoxon Z-Statistics<br>Comparing different Exposure Groups | | |
|---|---|---|
| Exposure Group 1 | Exposure Group 2 | Z-Statistic |
| 1 | 2 | 0.779 |
| 1 | 3 | 0.629 |
| 1 | 4 | 0.134 |
| 1 | 5 | 0.728 |
| 1 | 6 | 0.919 |
| 1 | 7 | 1.047 |
| 2 | 3 | 1.325 |
| 2 | 4 | 0.266 |
| 2 | 5 | 0.240 |
| 2 | 6 | 0.410 |
| 2 | 7 | 0.745 |
| 3 | 4 | 0.473 |
| 3 | 5 | 1.153 |
| 3 | 6 | 1.212 |
| 3 | 7 | 1.253 |
| 4 | 5 | 0.185 |
| 4 | 6 | 0.235 |
| 4 | 7 | 0.363 |
| 5 | 6 | 0.000 |
| 5 | 7 | 0.577 |
| 6 | 7 | 0.707 |

Z-statistics derived from Wilcoxon effect sizes.

**Table 4** Pairwise Wilcoxon Z-statistics comparing baboon testing exposure trials (1–7), showing relative differences in response scores between each group pairing. Z-statistics are derived from Wilcoxon effect sizes. Each row represents a unique pairwise comparison.

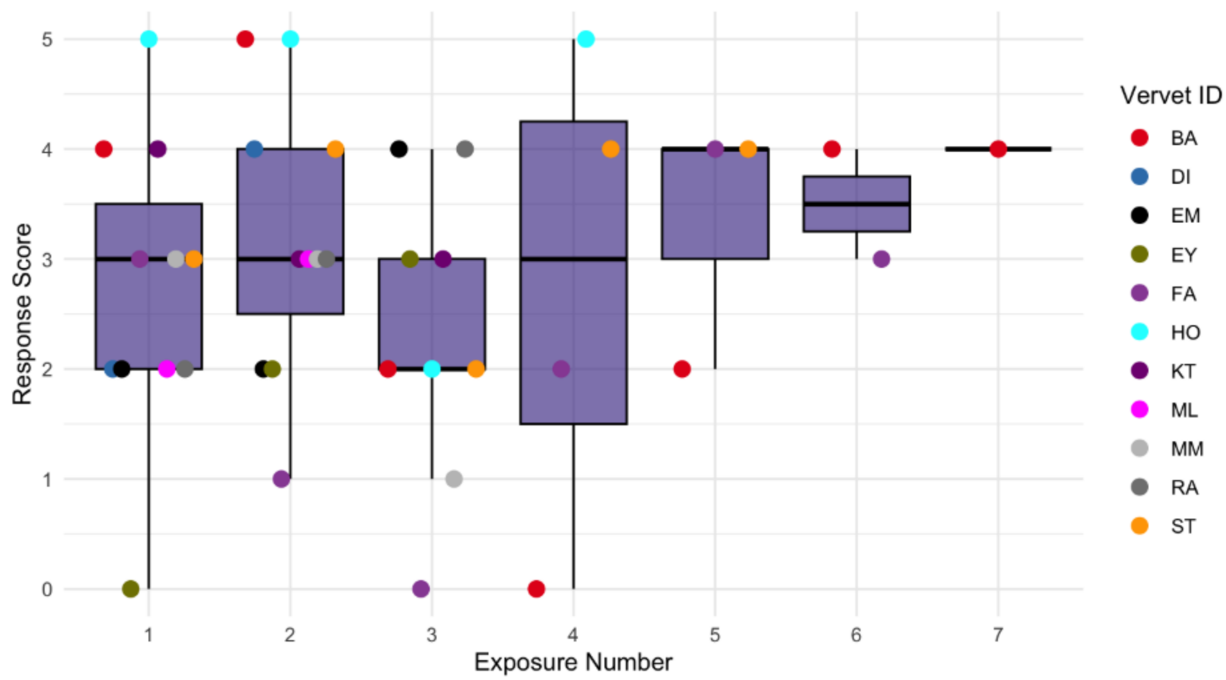


**Figure 4** Boxplot of individual vervet monkey scores in the baboon exposures they witness, with a maximum of 7 exposures, showing outliers and distribution of response scores. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge to represent the IQR. The whiskers reach 1.5 * IQR.

**Dogs.** A Wilcoxon-Signed Rank test comparing dog test scores of first and second exposure indicated that although the median test scores increased by 0.75, there was no significant difference in response between the two test events (Z=-1.477977, p = 0.130) despite a moderate effect size (0.482). Figure 5 highlights a median shift from a score of 3 in the first exposure to 4 in the second exposure. The dog used in the first exposure was larger than the one used in the second exposure, which may explain the difference seen in the median scores. Although these results are non-significant, it is moving in the direction of being consistent with my prediction.

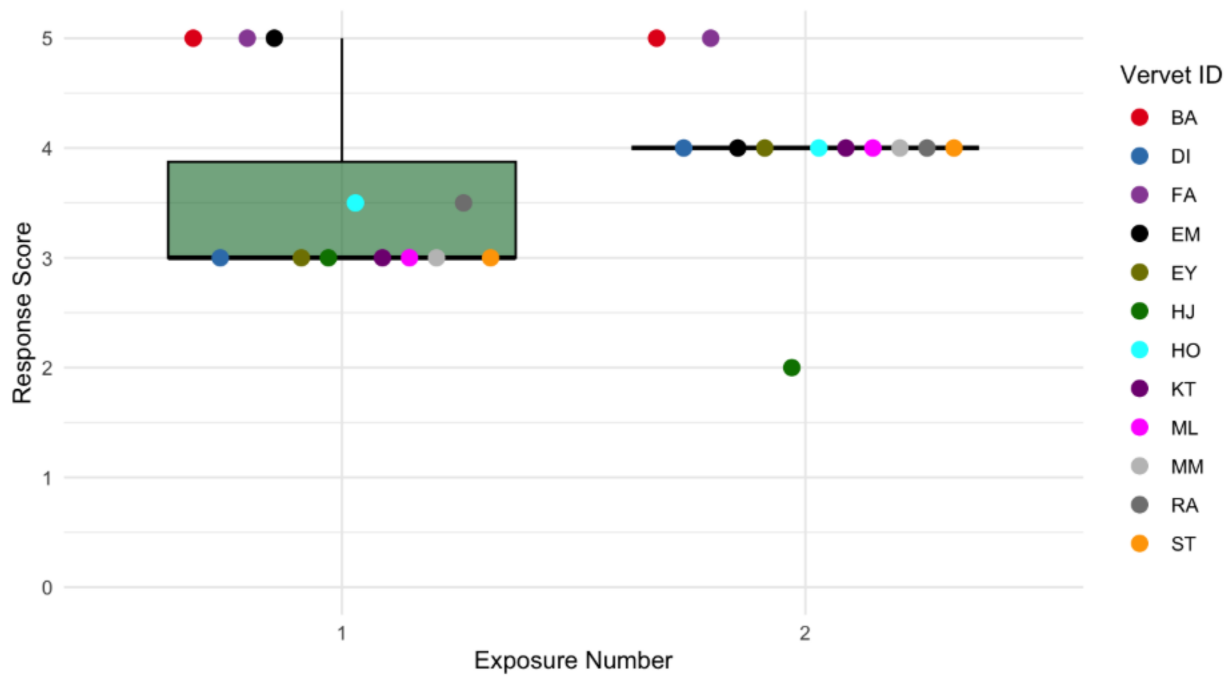


**Figure 5** Boxplot of individual vervet monkey scores in exposure 1 and 2 of dog training**.** Horizontal line indicates median score across all individuals, and vertical lines ("whiskers") extend from the hinge represent 1.5 * IQR.

**Humans.** A Friedman test on response to humans across the vervet individuals showed a statistically significant relationship between exposure number and response score (Friedman chi-squared = 14.711, df = 2, $p < 0.001$, N = 12). However, in contrast to the prediction, an analysis of median differential indicates a negative relationship between vervet response and human exposure, such that increased exposure to humans resulted in a reduction in intensity of vervet response. Figure 6 highlights that on first exposure, the median response score was reasonably high at 4 but then decreased to 1 on the second exposure and remained at the same level for the third exposure. The three humans used in the encounters represented a few differing physical characteristics like sex/gender, size, age, and ethnicity, which could have contributed to the variation seen in the response scores.

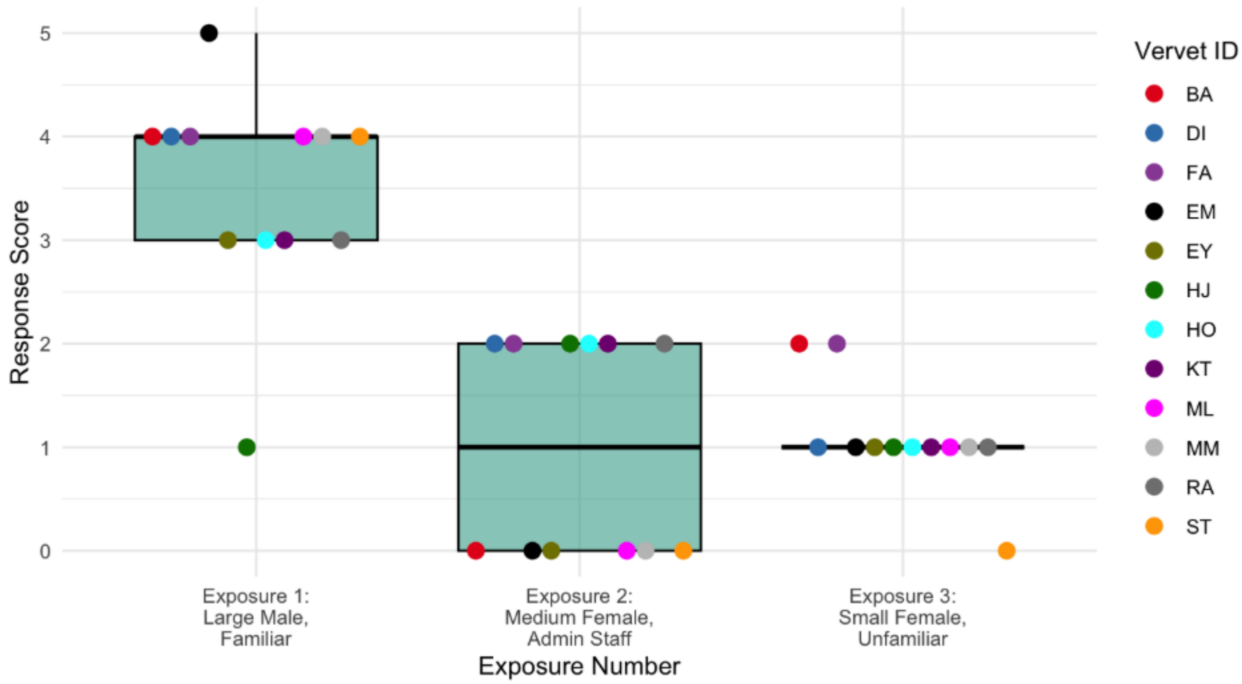


**Figure 6** Boxplot of individual vervet monkey scores in exposure 1, 2, and 3, showing outliers and distribution of response scores to humans. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

**Snakes.** Consistent with the prediction, analysis of the snake threat tests revealed a positive trend in response scores across exposures (Exposure 1-2 [2], Exposure 2-3 [0], Exposure 1-3 [2]), that was statistically significant (Friedman's $\chi 2 = 20.762 = 20.762$, df = 2, $p < 0.001$, N=12; large effect size r = 0.865). Because the overall effect was significant, a post-hoc analysis was conducted. As can be seen in Figure 7, a series of Wilcoxon-Signed Rank tests indicated the significance was primarily driven by the increase in response scores between exposures 1 and 2 ($Z = 0$, $p = 0.0065$), which was maintained for the third exposure. It should be noted that the first exposure was a distant encounter with a live snake outside of the vervet enclosure, which may explain the low scores, as the snake was not inside the enclosure like the snake model exposures thereafter.

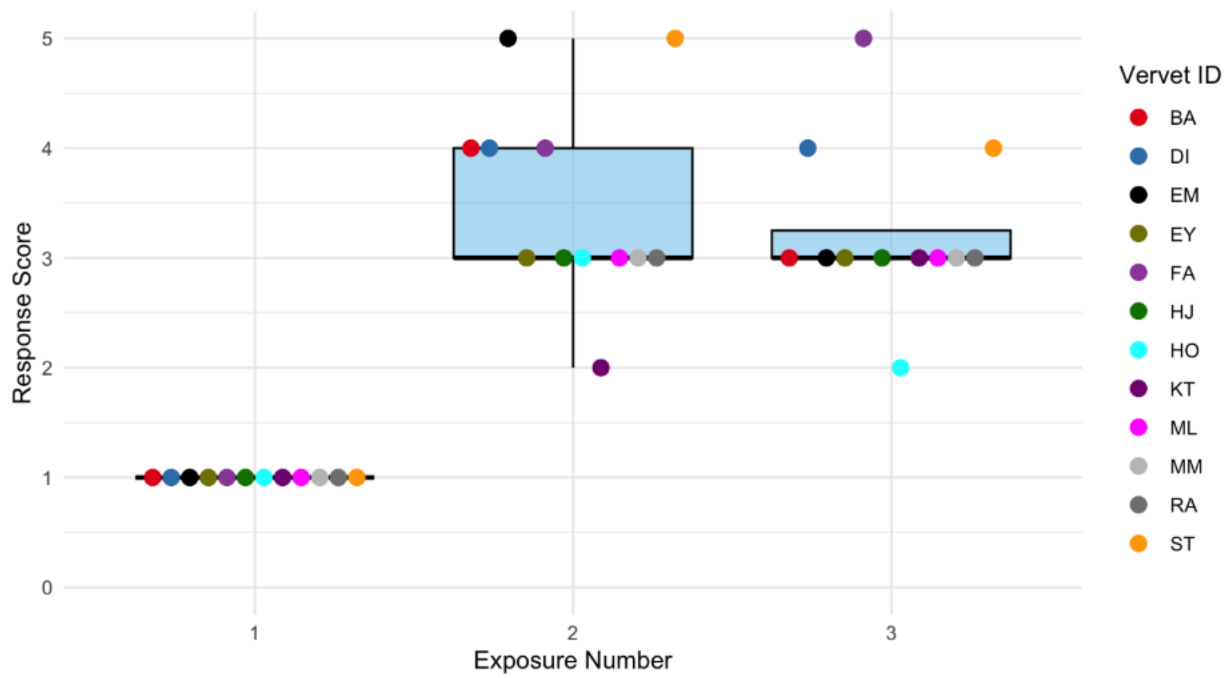


**Figure 7** Boxplot of individual vervet monkey scores in response to snakes, in exposure 1 (ad hoc), 2, and 3. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge represent the IQR. The whiskers reach 1.5 * IQR.

**Prediction B:** With each exposure to electrical wire, the number of shocks will decrease per individual.

Consistent with the prediction, as vervet individuals progressed through multiple exposures, the number of shocks they received decreased (Friedman chi-squared = 20, df = 2, p-value < 0.0000454, N=12), (Exposure 1–2:  score 1, Exposure 2–3: 0, Exposure 1–3: 1). As can be seen in Figure 8, the significant reduction in shocks by exposure number was driven by the reduction from a variable number of shocks in the first exposure to electric cables to 0 shocks in the second exposure which was maintained in the third exposure (Exposure 1-2: p= 0.0085, Exposure 2-3: no change, Exposure 1-3: p= 0.0085).

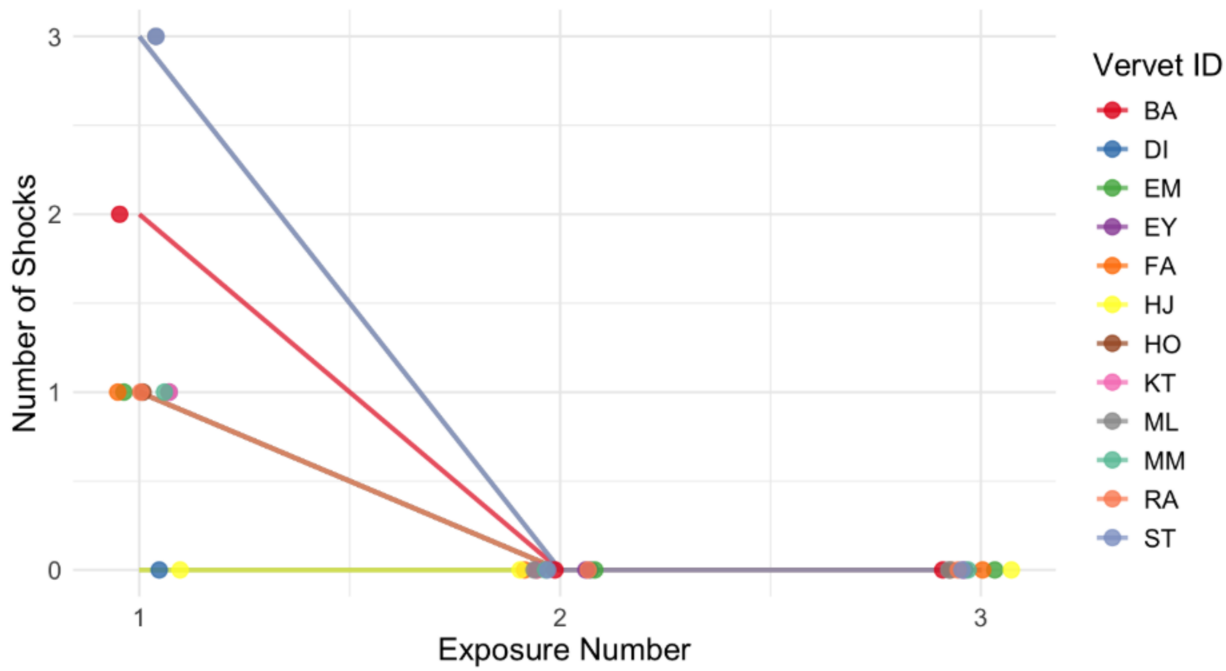


**Figure 8** Individual number of shocks received per individual by number of exposures to electric cables.

**Hypothesis 2**- Individuals who observe negative reactions to threats by others will learn to be afraid of the threat (at least partially) through social learning.

**Prediction A:** If a vervet monkey observes another individual receiving a shock, they will experience fewer shocks than individuals who do not observe a peer receiving a shock.

The total number of shocks received was not influenced by the number of shocks an individual observed before directly interacting with electrical wires themselves (Spearman rank correlation test: S = 270.12, p = 0.864, $rho_{12}$= 0.06; Figure 9).

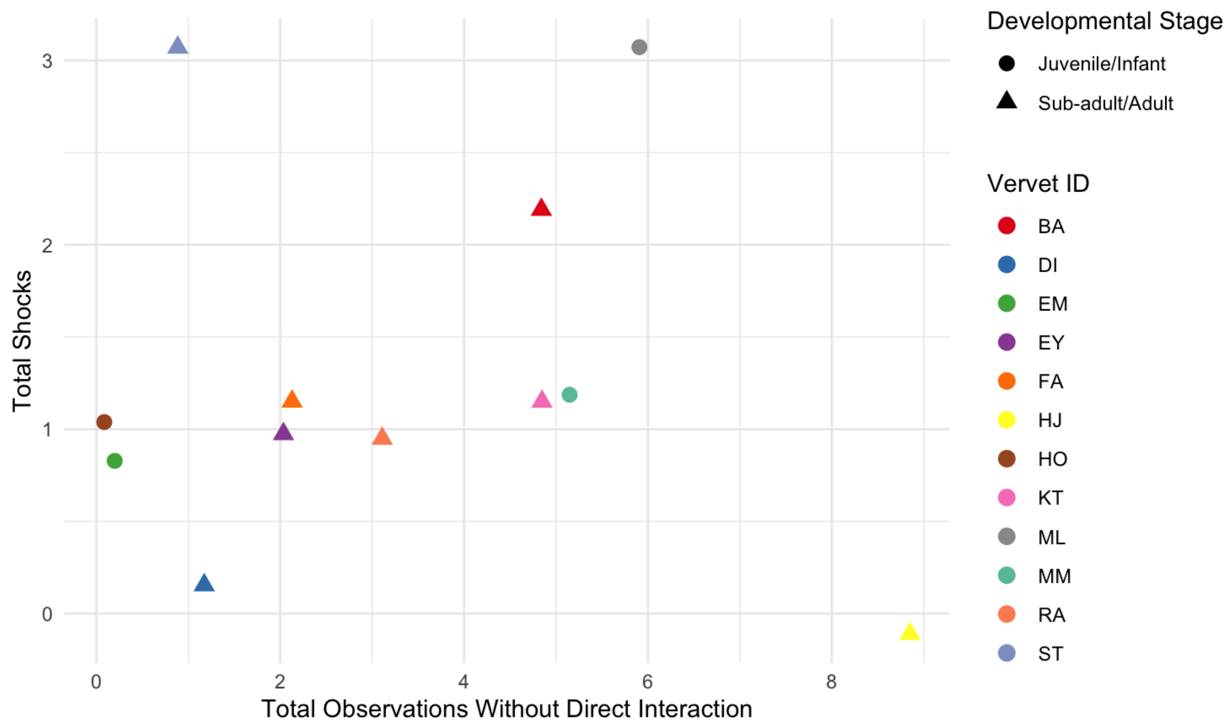


**Figure 9** Scatter plot shows each individual's total number of shocks and number of observations of others being shocked without a previous direct interaction with the electrical wires.

### 3.1.2 Discussion

When testing my first hypothesis, which suggests that an individual's scores should improve with continued exposure to threats, only one out of the four threats (snakes) showed a significant relationship in the predicted direction. However, with a small sample size, it is useful to consider the details of the threat tests that may have played a role in the results.

**Baboons.** During the baboon tests, there were no significant changes in response score with repeated exposures. While there appears to be an upward trend across the 7 encounters (Figure 4), there are a few factors that could have played a role in the absence of significance. Firstly, the baboons featured in the exposures varied in size, sex, age, and number, which may have played a role in the variation in scores across exposures. Additionally, the vervet group size for this study was already quite small in comparison to current literature, which has reported sample sizes ranging from 20 to over 90 individuals (Junker *et al*. 2020), and as the exposure numbers increased, fewer vervets were present to provide response scores because not all of the individuals were present during every ad hoc exposure. Only one individual was present for all 7 baboon exposures. Also, the median response scores only dropped below a score of 3 once, indicating the Release group had been responding relatively well to the baboons upon first exposure (Donaldson 2017). Baboons fall under the category of carnivorous mammalian predators to vervet monkeys and typically trigger the individuals to move away from the threat quickly and silently (Seyfarth et al. 1980a). The baboons approached the enclosures mostly during the dry season (December – May), meaning that any individual who had been living at Colobus Conservation before March 2011 (HJ, KT, FA, BA, EY, ST, DI, and EM) would most likely have been exposed to baboons previously. Prior habituation to the baboons during rehabilitation at Colobus Conservation could have potentially influenced the response scores by reducing the perceived threat. Nevertheless, since all initial responses were adequate, I conclude that habituation did not compromise the integrity of the threat assessment scores.

**Dogs.** While there was an increase in the median dog response score across exposures, the change wasn't statistically significant. The first dog presented to the Release group during awareness tests was a larger dog, which differs from the subject used in the second exposure, which was a smaller individual. Dogs of all sizes pose a threat to vervets, but response intensity may be influenced by such factors, depending on how threatening a predator appears. The typical vervet response to mammalian carnivores is to run to a tree and climb up to avoid the attack (Seyfarth *et al.* 1980a); however, if the dog is small enough or appears less threatening, vervets are also known to approach and mob (Struhsaker 1967). A lower response score due to individuals not climbing upwards and away would not, therefore, necessarily reflect “inappropriate” behaviour. While I cannot be certain which characteristics illicit stronger and appropriate responses, the physical difference between presented threats may explain why we see a difference in response in exposure numbers. Furthermore, the median response score was relatively high during the first exposure, suggesting that the group may have already been responding appropriately to dogs, reducing the opportunity for a significant change to occur.

**Humans.** Interestingly, the median human exposure response score was initially high but then showed a significant decrease in exposures 2 and 3. In this study, the humans who were used in the exposures represented a diverse range of characteristics, including sex/gender, size, age, and ethnicity. The first exposure was an adult, Kenyan man, with a relatively large build, which may explain why this exposure received the highest median response score, as a larger human may be perceived as more of a threat (McElvaney *et al* 2021). However, this individual was also the most familiar to the vervets as he participated in the rescue of some of the individuals and provided rehabilitation care. The second exposure was an adult, Kenyan woman of medium build. This human was not as familiar to the vervet group, but the individuals may have seen her around the enclosure as she was admin staff at Colobus Conservation Trust. The third exposure was an adult Spanish woman who had the smallest frame of all the human encounters. She was the most unfamiliar to the monkeys and had rarely been seen by the vervets. I cannot disentangle the explanations for the decrease in vervet response with human exposures. It could be due to habituation to human presence or the reduction in size (and hence threat) of the humans from exposure 1-3. Although not the focus of this study, it is interesting to note that when examining the differing characteristics among humans, it appears that the vervets responded most appropriately to the larger, familiar, Kenyan man.

**Snakes.** In the planned model snake exposures, the model did not replicate a specific species of predatory snake, like a python, yet would still present the vervets with a potential cue to a deadly hazard (Schad *et al*. 2024). Here, a significant difference was observed between the exposure scores, with the largest change occurring between exposure 1 (a live snake outside the enclosure) and exposure 2 (a model snake within the enclosure). The significant relationship was positive, suggesting that over repeated exposures, the vervet monkeys learned to react more appropriately to the presence of a snake. However, due to the differing conditions between exposure events, I cannot be certain that the change between the first two exposures was due to improved responses to the presented threat. The live snake being located outside of the enclosure at a safe distance may not have been perceived as a big threat compared to the model snakes inside the enclosure in the subsequent exposures as they were in a closer proximity, especially if it was not a predatory species (Isbell and Etting 2016). Typically, vervets will inspect a snake prior to producing an alarm call or reaction, which requires them to be in proximity to the threat to identify the species and determine if it is a threat (Schad *et al.* 2024). Additionally, it has been reported that vervets will not move from a position in an arboreal location if a snake is spotted, which, in this study, may have been reported as a score of 1 if a vervet exhibited this behaviour because they did not adjust their positioning, but in reality, reflects an appropriate response (Seyfarth *et al*. 1980a). If the vervets did not register the real snake as a threat from inside the enclosure, that would explain why the reactions did not score higher. Knowing this, one can look at the median score difference between exposure 2 and 3 to have a better understanding of how this group specifically responded to model snakes within their enclosure. Exposures 2 and 3 both had a median score of 3; while not the highest possible score, this is considered an adequate response to this specific threat. In summary, the model snake used in this study prompted appropriate responses from the Release group.

Across all threat awareness trials, the vervets would likely have been exposed to all the threats while in the enclosure, but before official data collection. Baboons often entered the Colobus Conservation area, so the vervet individuals would have learned about their presence, but with the protection of the enclosure. Similarly, snakes and stray dogs would have also been spotted in the surrounding area, but may not have been registered as a threat, as they would have been further away in foliage, and the enclosure provided security. This may explain why median scores across all threats were rarely above a 3 because the group may have become habituated to the enclosure, providing safety from threats. In support of this, it was found that urban vervets had a shorter flight initiation distance (meaning a threat is closer prior to an individual responding) than rural ones, suggesting that urbanised environments provided security and may result in habituation to threat (typically human) presence (Mikula *et al.* 2018). It is also possible that the awareness tests did not resonate with the vervets properly; this could be a result of not using a negative stimulus in association with the threat. As seen in previous research, the pairing of a negative stimulus with a threat, known as classical conditioning, reinforces adequate prey behaviour. Without the negative stimulus, the individual is simply being presented with the threat, and there is no connection made between the threat and danger (Pavlov 1927; Griffin *et al*. 2001).

There was a significant decrease in the number of shocks as exposure to electrical wires increased. The vervet group learned to avoid electrical wires after the first exposure and maintained this knowledge in the following exposures. In training, the shocks were a lower voltage and pulsing current, compared to when in the wild, where one touch of an electrical wire is typically fatal (Cunneyworth and Slade 2021). Only two individuals did not touch the wires (and receive a shock) during the entire training period, so the majority did experience a shock during the training. If that occurred in the wild, it would have most likely resulted in death, solidifying the need to pursue pre-release training to prevent a lethal encounter with electricity in their release environment. Electrical wires were an important threat to vervets in the Diani area, with 3 vervet electrocution welfare cases from non–study groups brought to Colobus Conservation from May 2012 to November 2013. Additionally, a study on 4 different non-human primate species found that 73% of reported electrocution cases were fatal in the Diani area (Cunneyworth and Slade 2021). Considering the demonstrated quick learning period and threat severity post-release, electrical training of the type used here would seem essential in rehabilitation training for individuals who are to be released into an environment with electrical wires.

Social learning is one of the key ways that vervets develop appropriate behaviour in the wild, typically by learning from older and higher-ranking individuals (van de Waal *et al*. 2010; van de Waal *et al*. 2013; Whiten and van de Waal 2018; Harrison 2024). My second hypothesis explored whether social learning had an effect on threat awareness, specifically to electrical wires. My findings did not support my prediction that social learning would aid learning, as they suggest that the number of times a vervet witnessed a shock, prior to receiving one themselves, did not reliably predict how many shocks they subsequently received in total. Although juveniles are often expected to rely on social learning more (Whiten and van de Waal 2018), this pattern did not appear in this group of 12 vervets (See Figure 9). In summation, merely observing another vervet receive a shock did not result in the vervets avoiding electrical wires. Experiencing a shock oneself was more effective as a deterrent in this study. It is important to note, however, that the small sample size of the Release group may have influenced the lack of significance in this analysis.

## 3.2 Research Question Two: How do individual differences among vervet monkeys affect their tests and training in rehabilitation?

### 3.2.1 Results

**Hypothesis 1 –** An individual's developmental age will influence threat awareness reactions during rehabilitation.

**Prediction A:** Across all threat awareness tests, threat awareness scores upon initial presentation (encounter 1) will be higher on average for the adult/sub-adult group compared to the infant/juvenile individuals.

An analysis of baboon response scores indicated that there was no significant difference between developmental age group (Juvenile/Infant $N_1$=5, Adult/Subadult $N_2$=7) in the initial baboon exposure scores (Wilcoxon Rank-Sum: $W = 15.5$, $p = 0.1$; Figure 10).

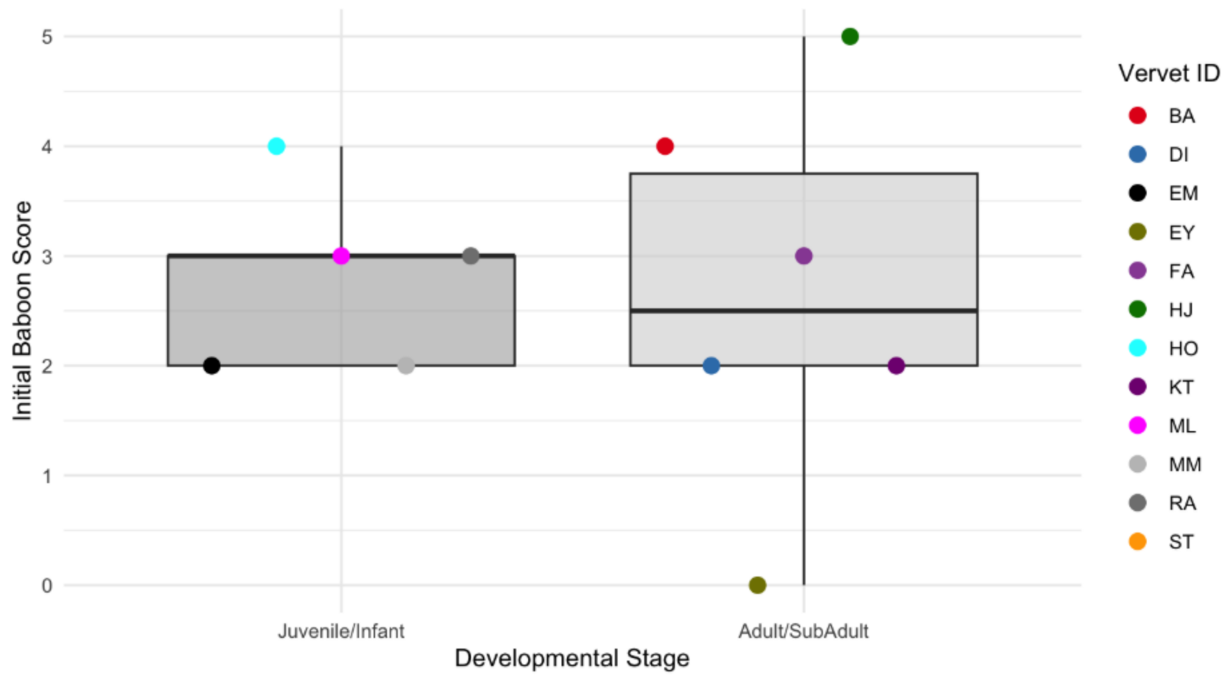


**Figure 10** Boxplot of individual vervet monkey scores upon initial presentation of baboon threat, in tests, by developmental age group. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

I also found that there was no statistically significant difference between developmental age groups (Juvenile/Infant $N_1$=5, Adult/Subadult $N_2$=7) in initial dog exposure scores (Wilcoxon Rank-Sum: W = 21, p > 0.5828; Figure 11).

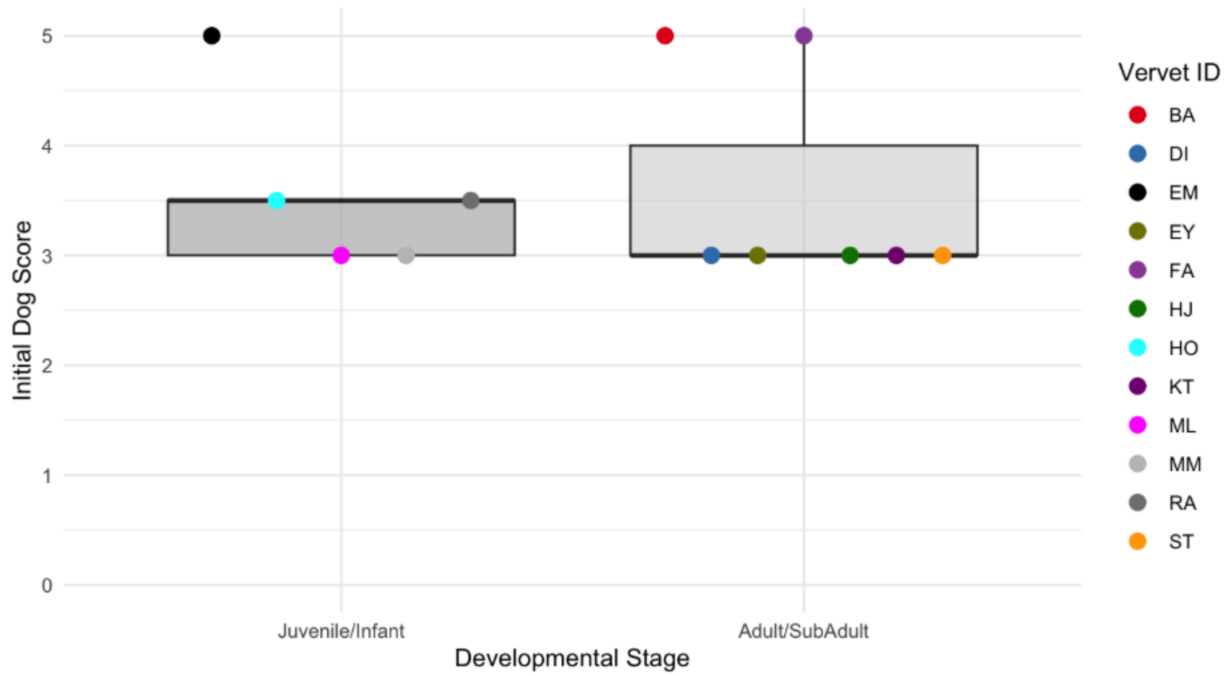


**Figure 11** Boxplot of individual vervet monkey scores upon initial presentation of dog threat in tests by developmental age group. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge represent the IQR. The whiskers reach 1.5 * IQR.

In contrast to the prediction, there was no statistically significant difference between development groups (Juveniles/Infants $N_1$=5, Adult/Sub-adults $N_2$=6) in initial human exposure response scores (Wilcoxon Rank Sum test: W = 21, p-value = 0.5956). Figure 12 highlights that the juvenile/infant category had a higher median score than the adult/sub-adult category. The difference between the two categories was 0.5 of a score, this opposes my prediction that the adult/sub-adult individuals would have a higher median score.

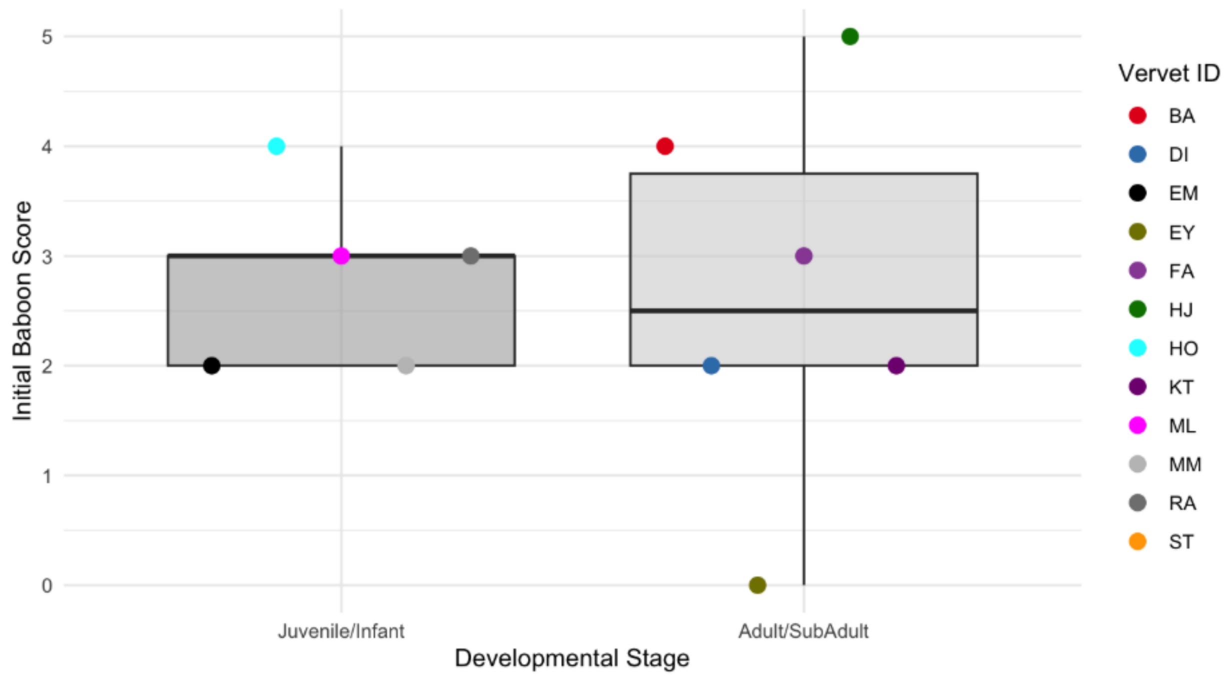


**Figure 12** Boxplot of individual vervet monkey scores upon initial presentation of human threat in tests by developmental age group. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

Finally, there was no statistically significant difference between developmental age group (Juvenile/Infant $N_1$=5, Adult/Subadult $N_2$=7) in the initial snake model exposure scores (Wilcoxon Rank-Sum Test: W = 14.5, p-value = 0.6616; Figure 13).

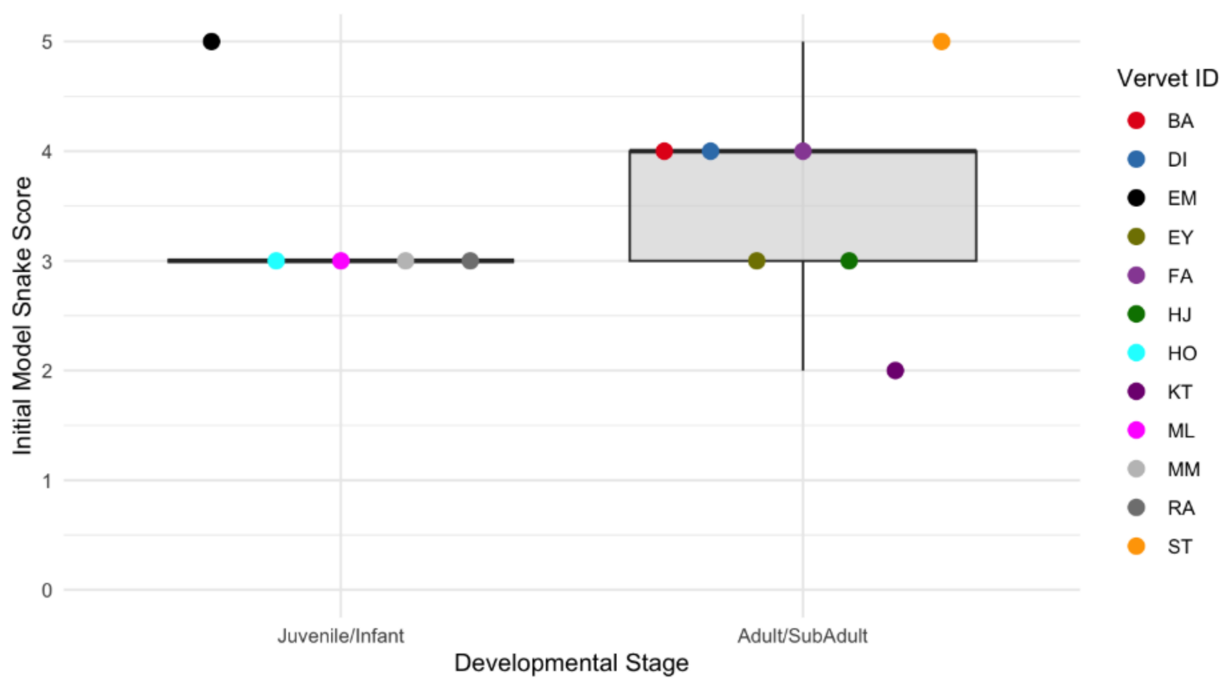


**Figure 13** Boxplot of individual vervet monkey scores upon initial presentation of snake threat, in tests, by developmental age group. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extends from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

**Prediction B:** As developmental age increases, there will be a decrease in the number of shocks upon initial exposure to electrical wires.

There was no statistically significant difference between developmental age groups in shocks received on first encounter with electrical wires (Wilcoxon Rank-Sum: W = 14.5, p-value = 0.6493). The two developmental stages (Juvenile/Infant $N_1$=5, Adult/Subadult $N_2$=7) received the same median total shocks, neither supporting nor refuting my prediction; however, the hinge was larger in the adult/sub-adult category (Figure 14), indicating that the central 50% of the scores were more widely dispersed and there was less consistency among the vervets in comparison to the Juvenile/Infant group.

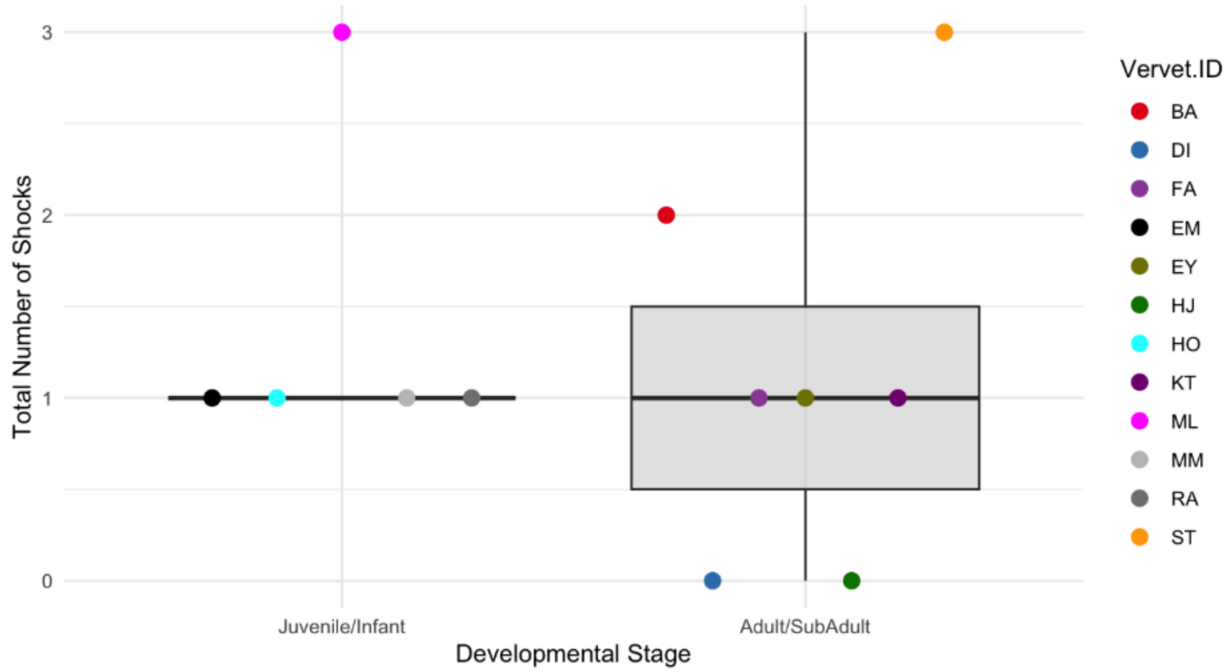


**Figure 14** Boxplot of individual vervet monkey shock number upon initial presentation of electrical wire, in training, by developmental age group. Horizontal lines indicate the median score across all individuals. The vertical lines ("whiskers") extend from the hinge (upper and lower box edges), which represents the IQR. The whiskers reach 1.5 * IQR.

**Hypothesis 2 -** Individuals who experienced captivity prior to arriving at Colobus Conservation will show a higher frequency of inappropriate behaviours in threat tests and training.

**Prediction A:** Individuals who have previous experience in captivity prior to arriving at Colobus Conservation will start with lower scores in baboon, dog, human, and snake awareness trials than individuals who have never experienced captivity.

There was no statistically significant difference between captivity backgrounds (No Captivity $N_1$=7, Captivity $N_2$=4) in the initial baboon response scores (Wilcoxon Rank-Sum test:

W = 20, p-value = N/A). Figure 15 shows the similarities between the captivity backgrounds and baboon score, with a median score difference of 0.5.

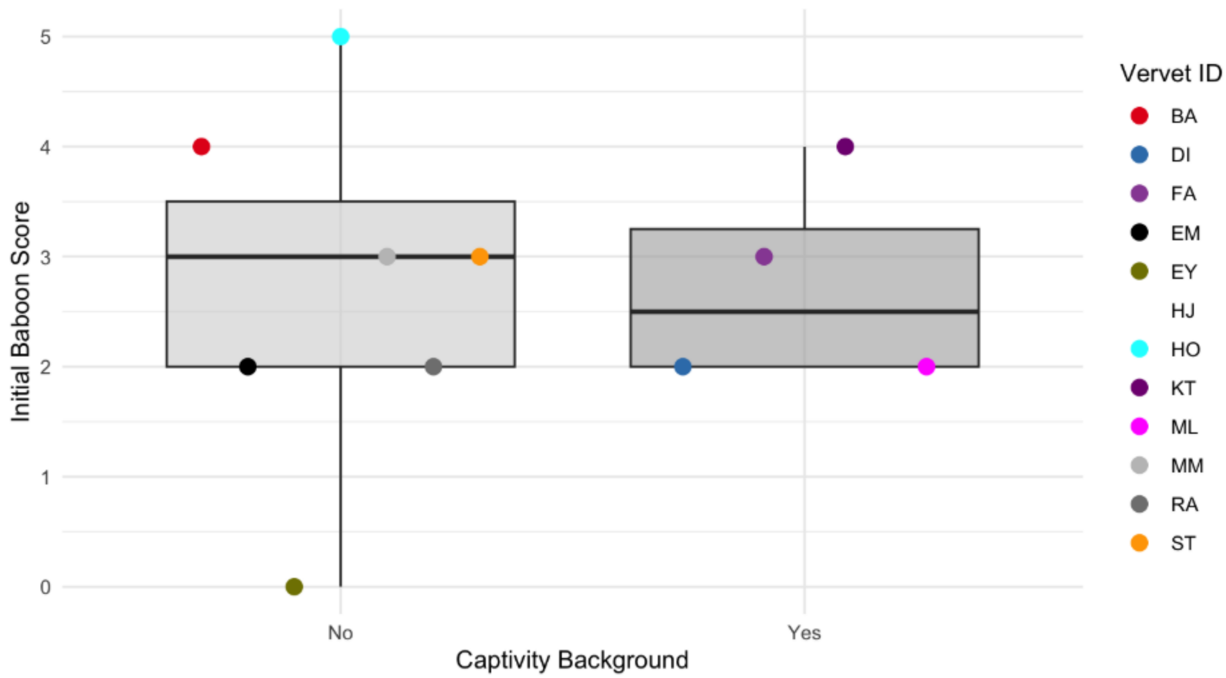


**Figure 15** Boxplot of individual vervet monkey scores upon initial presentation of baboon threat, in tests, by captivity background. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

There was no statistically significant difference between captivity backgrounds (No Captivity $N_1$=7, Captivity $N_2$=5) in the initial dog response scores. (Wilcoxon Rank-Sum test: W = 14.5, p-value = 1).

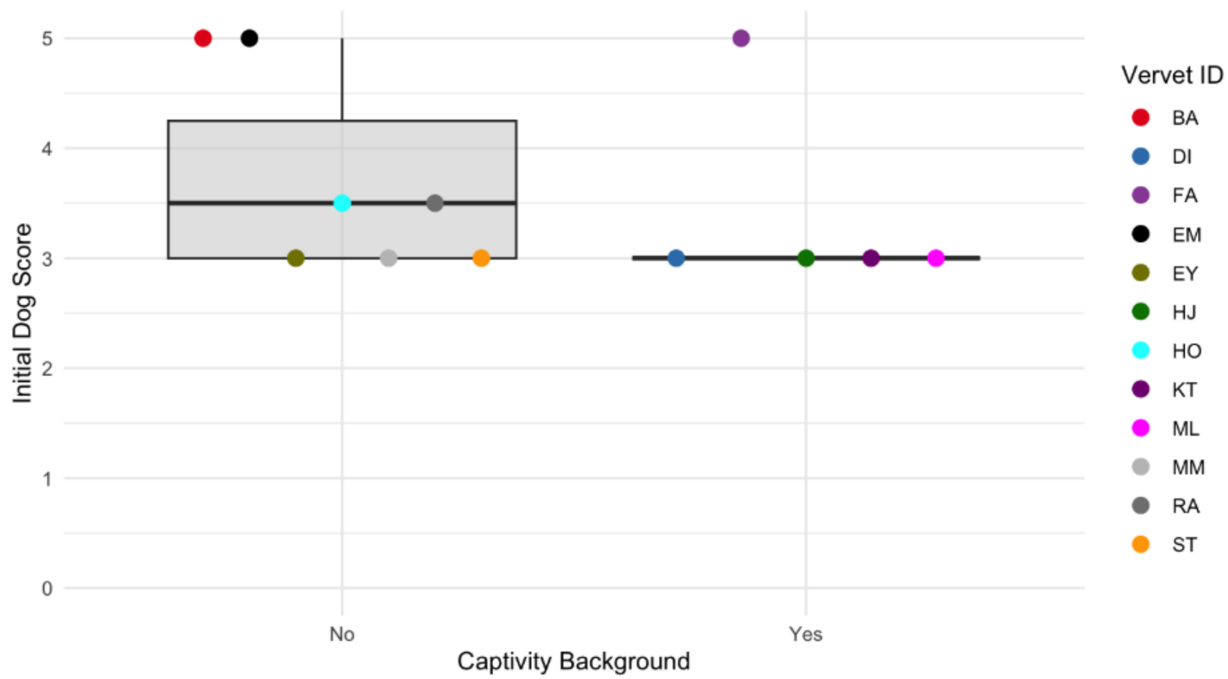


**Figure 16** Boxplot of individual vervet monkey scores upon initial presentation of dog threat, in tests, by captivity background. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

There was no statistically significant difference between captivity backgrounds (No Captivity $N_1$=7, Captivity $N_2$=5) in the initial human response score (Figure 17; Wilcoxon Rank-Sum: W = 24.5, p-value = 0.3171).

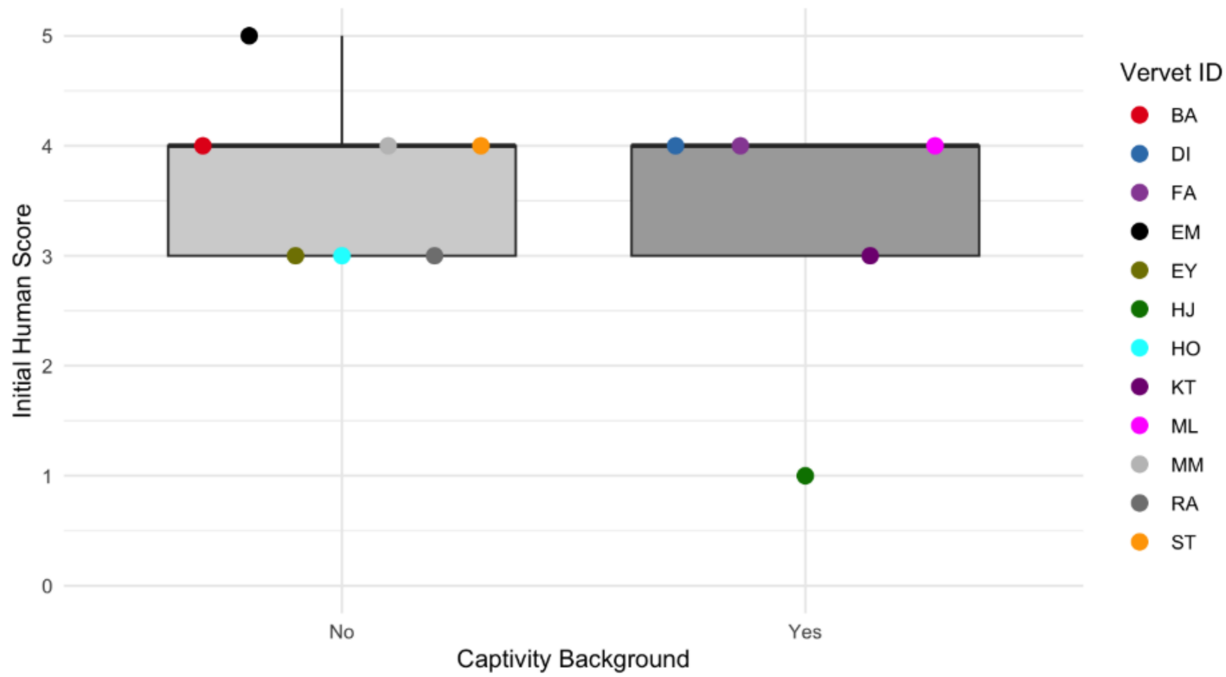


**Figure 17** Boxplot of individual vervet monkey scores upon initial presentation of human threat, in tests, by captivity background. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

Lastly, there was no statistically significant difference between captivity backgrounds (No Captivity $N_1$=7, Captivity $N_2$=5) in the initial model snake scores, excluding the initial ad-hoc, live snake encounter (Wilcoxon Rank-Sum: W = 20, p-value = 0.7235). Figure 18 highlights the similarities between the two captivity groups, where both captivity categories had the same median score, disputing my prediction.

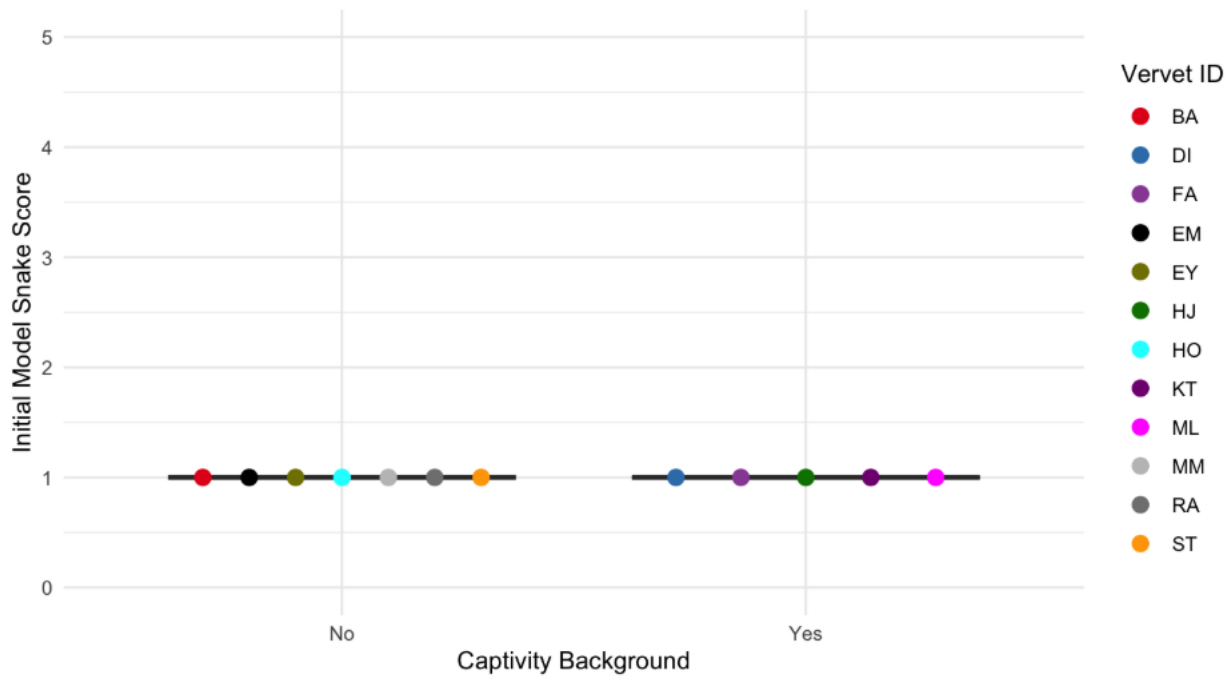


**Figure 18** Boxplot of individual vervet monkey scores upon initial presentation of snake threat, in tests, by captivity background. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

**Prediction B:** Individuals who come from a captive background will have a higher frequency of touches of the electrical wire than non-captivity-experienced vervets during their initial exposure in training.

There was no statistically significant difference between captivity backgrounds (No Captivity $N_1$=7; Captivity $N_2$=5) in the total number of shocks received (Wilcoxon Rank-Sum: W = 23, p-value = 0.3599). Figure 19 indicates that the vervets who did not have a background in captivity had the same median number of shocks upon initial presentation of electrical wires as the group that did experience captivity prior to joining Colobus Conservation.

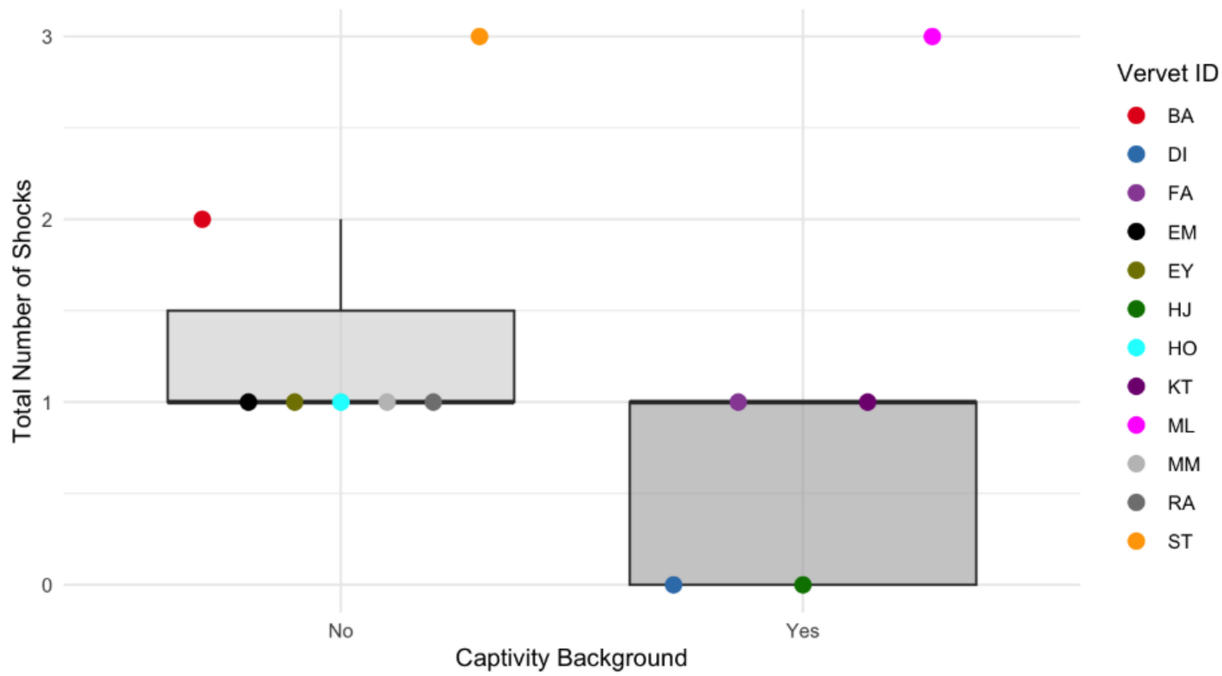


**Figure 19** Boxplot of individual vervet monkey shock count upon initial presentation of electrical wire, in training, by captivity background. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

### 3.2.2 Discussion

My second research question focused on how individual experiences and characteristics might influence responses in threat awareness tests and electric wire training. Previous research has revealed that predator response is not only formed via the evolutionary process but also the "accumulation of experiences during individual lifetimes" (Griffin et al. 2001, pg. 1319), which implies that older individuals may have had more opportunities to learn adequate responses to presented threats. Younger individuals are hyper-sensitive to threats and refine their responses with age, meaning they do not demonstrate specific reactions to differing threats, so one might expect them to respond less appropriately than the older group (Seyfarth and Cheney 1981;

Lingle *et al.* 2008; Dubreuil *et al*. 2023). None of my tests revealed a statistically significant difference between the two age groups; infant/juvenile and sub-adult/adult. There was also no statistical significance found between the two age groups in the number of shocks received in the electrical training. The findings may be a result of a small sample size, as previous research has indicated threat response is not static, and we would expect to see more inappropriate behaviours from the infant/juvenile group (Dubreuil *et al.* 2023). It is also important to consider that both age groups featured individuals from different captivity backgrounds, which makes it difficult to identify and isolate age as a factor that may impact their threat response.

My second hypothesis addressed the impact of previous captivity on threat awareness. Captivity often results in stress (Khan 2013) and the loss of essential threat responses (Mallapur and Choudhury 2003; Lutz and Novak 2005; Banks et al. 2018); therefore, vervets who had experienced captivity before entering Colobus Conservation may be expected to exhibit less appropriate responses to encounters with threats. While my data did not support my hypothesis, this could be attributed to the small sample size of my study. Also, both groups featured individuals of differing ages, which may have influenced response behaviour, and we cannot disentangle how much each variable influences or does not influence threat awareness tests. Additionally, individuals who experience extensive captivity may become hypersensitive to stimuli because of lower well-being and consequently demonstrate more fearful behaviour to threats (Mallapur and Choudhury 2003; Banks *et al.* 2018) than individuals who did not spend time in captivity.

## 3.3 Research Question Three: How does pre-release testing and training influence and/or predict post-release behaviour and success?

### 3.3.1 Results

**Hypothesis 1 – Pre-release threat awareness tests may predict post-release behaviour and success.**

**Prediction A:** The Release group of vervets will exhibit a similar rate of encounters with threats per month as the two control groups if the Release group presents appropriate response scores prior to release.

There were no electrocution cases in any of the vervet groups, so analyses were only conducted on threats that were encountered during the post-release period. There was a statistically significant difference between the three vervet groups in the rate of baboon encounters in the wild (Kruskal-Wallis chi-squared = 24.848, df = 2, p-value = 4.022e-06). Further analysis using a pairwise comparison showed that the significant difference was due to the University group having a higher rate of encounters than both the Release (p-value < 0.0001) and Hotel (p-value <0.0001) groups (Figure 20).

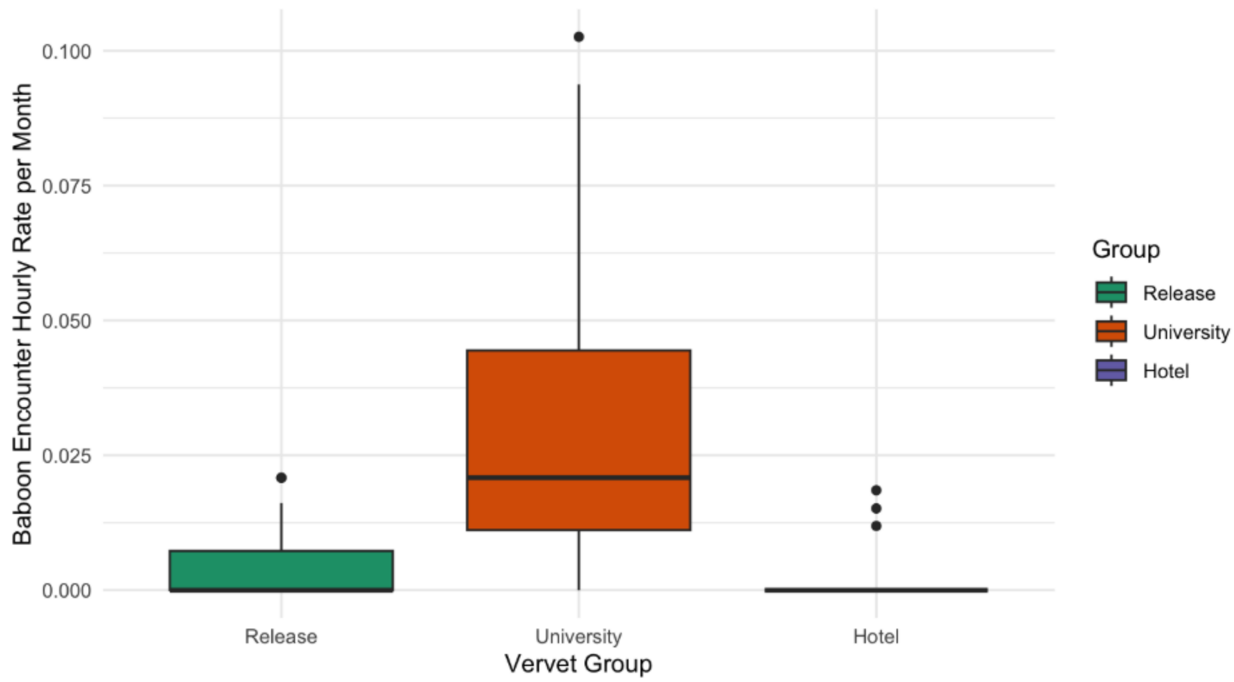


**Figure 20** Box plot of baboon encounter rates per hour per month by vervet group. The plot displays the median number of baboons encountered per hour for the Release, University, and Hotel vervet groups during observation periods. Horizontal lines indicate the median score across all individuals, and vertical lines ("whiskers") extend from the hinge represent the IQR. The whiskers reach 1.5 * IQR.

Furthermore, there was a statistically significant difference between the three vervet groups in the rate of dog encounters (Kruskal-Wallis chi-squared = 20.63, df = 2, p-value = 3.314e-05). Analysis using a pairwise comparison showed that the significance was due to the University group having a higher median dog encounter rate than both the Hotel (p-value = 0.000005) and Release (p-value = 0.0205) groups (Figure 21). The Release and Hotel group had a median encounter rate across all months of 0, while the University group had a slightly higher median of 0.0128.

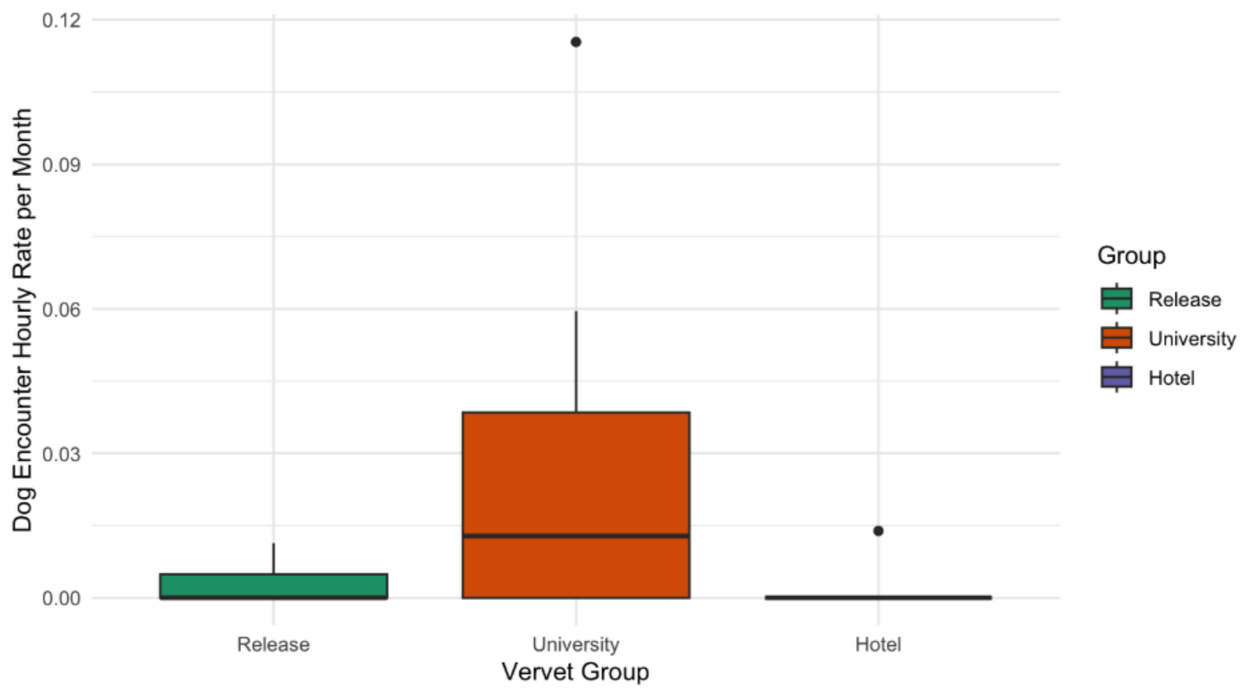


**Figure 21** Box plot of dog encounter rates per hour per month by vervet group. The plot displays the median dog encounters per hour for the Release, University, and Hotel vervet groups during observation periods. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR

Snake encounters were rare, and there was no statistically significant difference between the three vervet groups (Kruskal-Wallis chi-squared = 0.036528, df = 2, p-value = 0.9819). The release group had the lowest rate of encounters with snakes, while the University and Hotel groups had progressively higher rates, respectively. Figure 22 shows that all three groups had a median encounter rate across all months during observation of 0, with each group presenting one outlier from the one encounter they had during the entire research period.

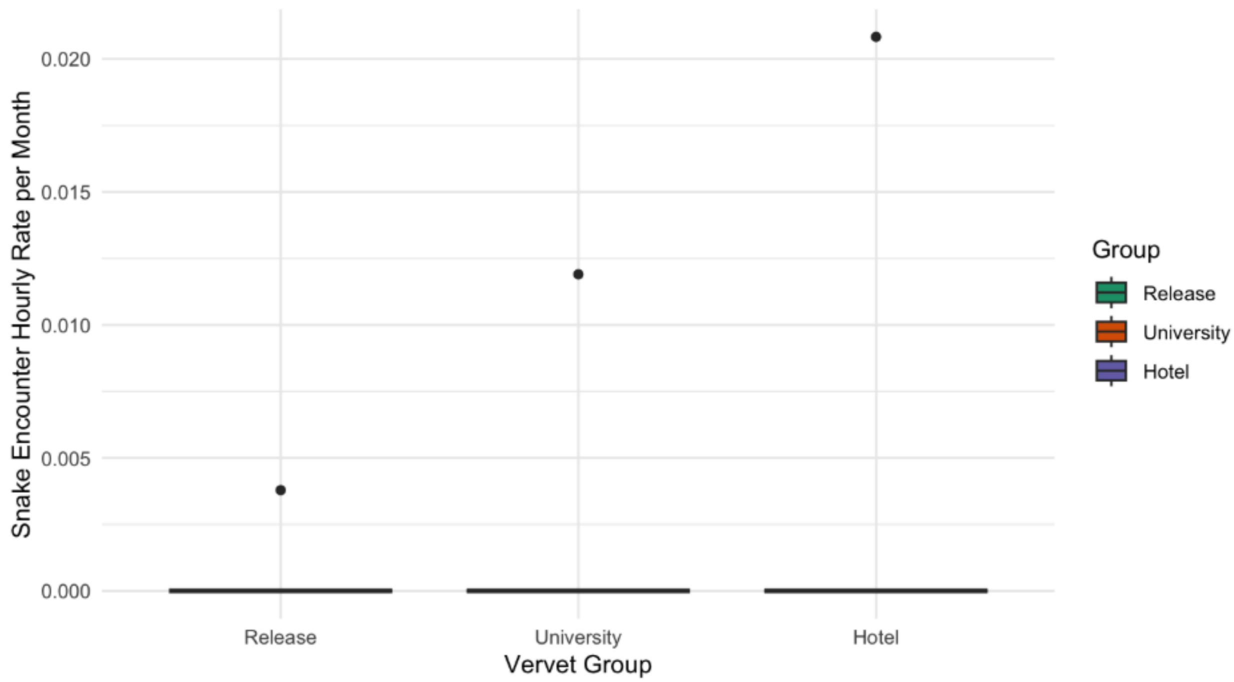


**Figure 22** Box plot of snake encounter rates per hour per month by vervet group. The plot displays the median snake encounters per hour for the Release, University, and Hotel vervet groups during observation periods. Horizontal line indicates the median score across all individuals, and vertical lines ("whiskers") extend from the hinge, representing the IQR. The whiskers reach 1.5 * IQR.

**Prediction B:** The Release group will demonstrate a similar death rate per 100 days as the two control groups.

Counting only confirmed deaths in the original cohorts, the Release group had a 66.6% survival rate during the time frame of May 28th, 2012 – November 30th, 2013. During this same timeframe, the University group had a 65% survival rate, and the Hotel group 90%. In a comparison of deaths per 100 observation days of each group, the Release group had a rate of 0.725, the university group 0.188, and the hotel group 0.188 (Figure 23). As reported by Donaldson (2017, p.124), there was no significant difference in survival rates between the three groups. Although mortality rates were higher in the Release group, differences among groups were not statistically significant (Poisson regression, $p = 0.215$).

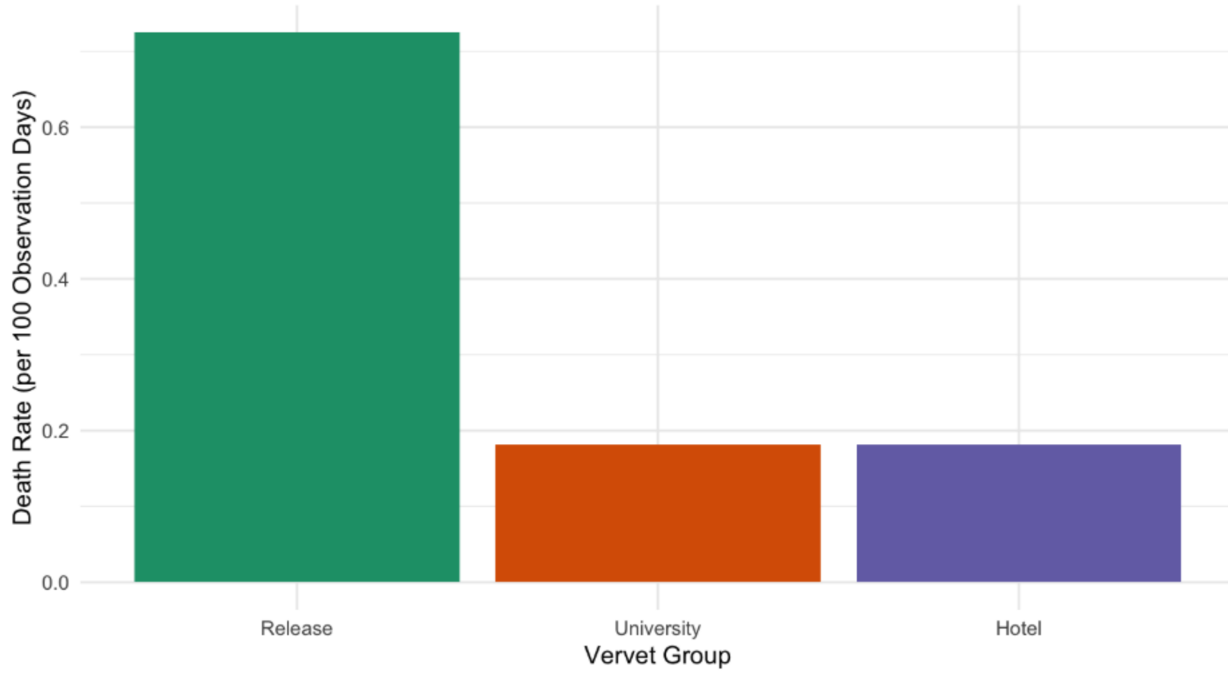


**Figure 23** Mean mortality rate (deaths per 100 calendar days) for the three vervet observation groups (Release, University, and Hotel) during the comparable post-release period (28 May 2012 – 30 November 2013). Bars represent the average number of confirmed deaths per 100 calendar days within each group.

**Prediction C:** The Release group will have similar causes of death to the control group.

An exploratory data analysis of the vervet individual's fates helped identify that the causes of deaths in the Release group were by humans (~40% of all deaths), vehicle (~20%), and other (~40% with no deaths due to baboons, snakes, dogs or electrocution (See Figure 24). Of the University group, 4% were killed by dogs, and the remaining were alive or missing at the end of the comparable time frame. Similarly, the Hotel group had 5% of individuals die due to human interactions. The Release group had two death types that were not reflected in the control groups: death by vehicle and other. There were no electrocutions in any of the vervet groups.

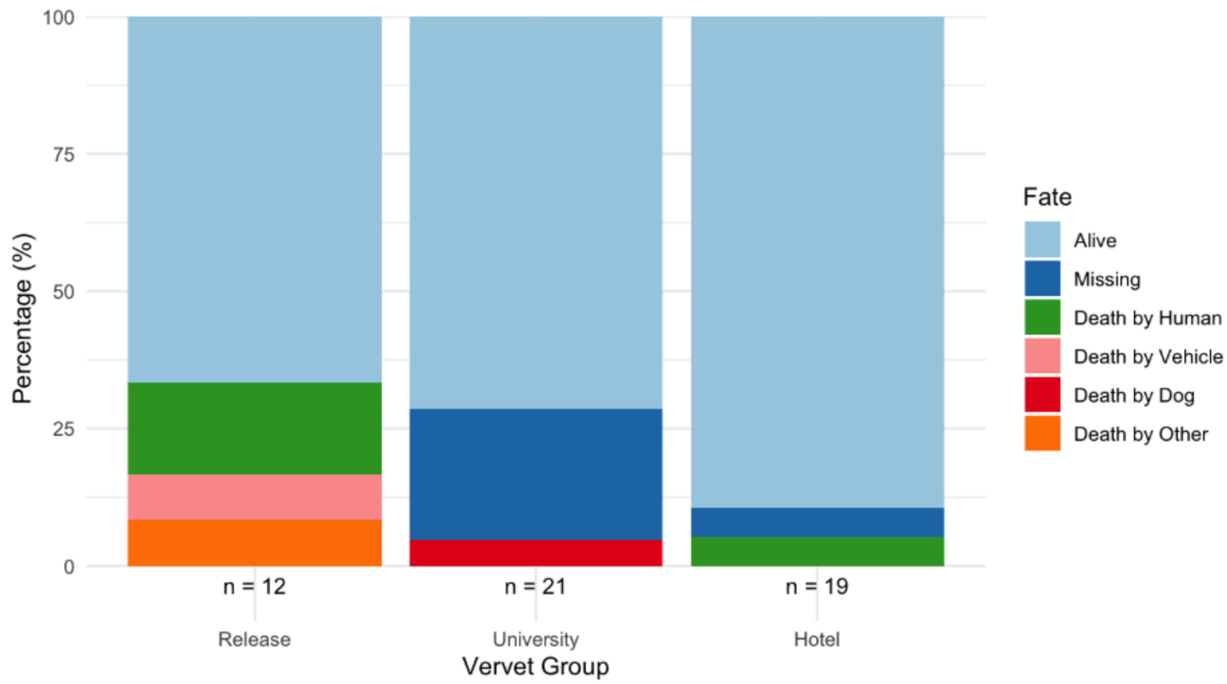


**Figure 24** Stacked bar plot showing the percentage of individual fates within each vervet group (Release, University, and Hotel) from a comparable time frame of May 28th, 2012 – November 30th, 2013. Fates include individuals that remained alive, went missing, or died due to various causes (human-related, vehicle collision, dog attack, or other/unknown causes). "Death by Other" encompasses any deaths that do not fit into the threats identified in this study, i.e. released too young or an inconclusive autopsy report. The individuals used in this comparison were the vervets who were present at the beginning of the timeframe; no immigration or births were included or considered.

### 3.3.2 Discussion

I explored whether pre-release threat awareness tests are predictive of behaviour and success, in addition to whether electricity training will positively impact behaviour and success post-release. I hypothesised that the threat awareness tests would predict behaviour and success after release.  Consistent with my prediction, the Release group's rate of encounters for the baboons, humans, and snakes was not significantly different from the control-Hotel group and, more impressively, was significantly less than the control-University group for baboons and dogs Thus, the Release group had the same or fewer encounters with these potential predators than the control groups, which is crucial as predation is the leading cause of death in releases (Beck et al. 1991; Strum 2005; Campbell et al. 2015).

The Release group did have a slightly higher rate of deaths per 100 calendar days than the two control groups, but these were not significantly different statistically (Donaldson 2017, p.124). It is crucial to consider that the Release group was observed more intensively than the Hotel and University groups, meaning every release individual was accounted for up until the moment their tracking collars were removed in 2013, 18 months post-release. The control groups did not have tracking collars, so there were more individuals with unknown outcomes, such that the recording of deaths was more conservative for the control groups than the Release group. The confirmed deaths were proportionally higher in the Release group, but this can be attributed to different data collection methods and the fact that the Release group was considerably smaller than the control groups.  Accordingly, the Release group seemed to be well prepared for life post-release; this could be a result of the electric-wire training or the requirement of exhibition of appropriate threat responses prior to release. There were no electrocution cases in the three vervet groups; however, there were three recorded electrocutions in the wider Diani area in other primate species during the 18 months. It is clear that the threat of electrical wires was still prevalent at that time, and the Release Group was successfully avoiding electrocution, further demonstrating the efficacy of the pre-release training Donaldson conducted.

The last aspect I explored in the success of the Release group was the causes of deaths in each group during the comparable time frame. While I did not statistically test the prediction that the Release group will demonstrate similar causes of deaths as the control groups, descriptive data indicated two causes of death in the Release group, which were not shared with the control groups - death by vehicle and an unknown cause of death. Due to an inconclusive autopsy of the unknown death, I cannot categorise the type of death or claim that it was not also reflected in the Hotel and University groups. There was one case of death by vehicle, suggesting that while tests to recognise and avoid motorised vehicles may reduce these types of deaths in rehabilitation release individuals, it is not the leading threat of concern for vervets, at least in Diani. The highest percentage of deaths in the Release group was via interactions with humans, and most notably, these deaths were mostly caused by humans wielding stone catapults and slingshots. This suggests that the threat awareness testing conducted in this study may not have been completely appropriate (or specific enough) for the release site or that their group was subject to slightly different levels of threats.

## 3.4 General Discussion

This thesis established that pre-release threat training and testing—particularly utilising aversive conditioning as seen in electrical training—is a viable and effective component of rehabilitation efforts in primatology, yielding post-release survival rates comparable to those of wild vervet groups in the same semi-urban environment. Furthermore, the data indicated that neither developmental age nor prior captivity status significantly limited an individual's pre-release learning ability. Nevertheless, these results simultaneously indicate the urgent requirement for developing more sophisticated training methods designed to mitigate risks from non-traditional anthropogenic threats, such as human-weapon conflict and vehicular traffic. To evaluate these outcomes comprehensively, my investigation continued by defining and quantifying the overall success of the release according to established conservation metrics, namely post-release survivorship/mortality rates (Tutin et al. 2008) and long-term population growth (Stoinski et al. 2003), which provided the framework for assessing the utility of individual pre-release performance.

Post-release success can be measured through post-release survivorship/mortality rates (Tutin *et al.* 2008) or long-term population growth (Stoinski *et al.* 2003). I determined the success of this rehabilitation release by considering the survival and threat encounters of the Release group in comparison to the other local vervet populations, specifically the Hotel and University groups. The released individuals had a similar rate of encounters with threats as the control groups and had a similar survival curve as the two control groups, indicating that the release and rehabilitation translocation performed can be considered successful in this context, as the vervet group met the 'appropriate response to threats' criteria for release, which accurately predicted the success of the group post-release. It is crucial to highlight that there was no true "control" group to compare with, as it would be unethical to release rehabilitated individuals without conducting threat awareness testing and training, so it's impossible to determine if the threat exposures and electricity wire training were the reason for the success. Additionally, in some cases, the median scores in the first exposure were adequate on an individual level (Donaldson 2017), indicating that further threat awareness testing might not have been necessary beyond a primary exposure.

Although this study may not pinpoint effective rehabilitation methods (other than with regard to electrocution training), it is clear that threats are the number one concern when it comes to post-release success (Beck *et al*. 1991), and this group of released vervets did not disproportionately succumb to the threats posed in the wild, indicating that there was an improvement upon previous release methods where individuals struggled post-release due to deaths via predators (Beck *et al.* 1991; Riedler *et al*. 2010; Cremona *et al*. 2017). Future research should focus on perfecting pre-release threat training and testing, particularly in threat response, without inducing habituation to the threats. Specific recommendations for achieving this are discussed below.

I found that neither the development stage nor the presence of captivity in a vervet's background significantly impacted behaviours in response to threat exposures. Individual differences among the vervets, whether by age group or prior history of captivity, did not indicate that any specific trait made them better prepared for encountering threats. Therefore, training can, and should, be performed with all pre-release individuals regardless of background or age. While my research used awareness tests (except for the electrical wires, which were categorised as training), the results of these trials are informative when thinking about future training attempts. However, this conclusion should be considered in light of the study's small sample size. It remains possible that age or captivity background may be found to be influential in future large-scale release attempts, so my recommendations remain flexible as future research develops.

Prey threat response is a behaviour built not only through the evolutionary process, but also through the conglomeration of experiences in an individual's lifetime, where individuals personally, and socially, learn the danger of predators and abiotic threats (Griffin *et al*. 2001). Understanding this should encourage future research to further explore how background might influence threat response and how that can be incorporated into rehabilitation to benefit all individuals. Due to a lack of prior experience, younger vervets may need more extensive threat training to develop their alarm calls, a skill that research shows improves with age and experience (Seyfarth *et al.* 1980b). Similarly, rehabilitation candidates who have a history of captivity are known to show higher levels of naivety to threats, suggesting that (despite my null findings) these individuals may need additional training to learn or relearn appropriate responses (Banks *et al*. 2018). It would be interesting to explore how age influences the efficacy of social learning and how that can be used to increase the success of pre-release training. Previous research indicates that younger individuals might rely more heavily on social learning than older ones (Arbon *et al*. 2025; Kendal *et al*. 2018), so social learning might be an appropriate method of training for younger individuals but less so for older individuals. To provide rehabilitation individuals with the best possible training and chances of success post-release, further research should aim to understand how individual differences might play a role in threat response while in rehabilitation. Doing so will provide invaluable information and guidance on future rehabilitation release techniques that can cater to primates in all developmental stages and backgrounds.

In this study, satisfactory response scores were observed prior to release, but deaths associated with known threats (humans) still occurred after the release. Pairing a threat with a stimulus or recorded alarm call is impactful when reinforcing specific behaviours such as threat responses in rehabilitation (Pavlov 1927; Seyfarth *et al.* 1980a; Mirza and Chivers 2000; Griffin *et al*. 2001). Although this type of training was only possible with the electrical wires, my study still provides valuable insight into the very real challenges that may present themselves in rehabilitation release cases and helps guide further exploration into this conservation method. After release, the vervets had one vehicular and two human-related deaths, which can be used to understand the shortcomings of the threat awareness tests performed before release. In both human-conflict cases, a projectile was used to injure and kill the vervet monkey, revealing that the human awareness tests performed might not have been specific enough to the dangers an encountered human may pose. Not all humans have the intent of hurting wildlife; however, a person holding a weapon should be avoided, so training vervets to identify common hunting and defence weapons may be useful but extremely challenging.  It might be beneficial to shift the direction of "human awareness training/test" from avoiding humans to recognising and reacting to the weapons/tools often used to kill primates.

On the other hand, vehicular deaths are common in Diani, but training a vervet to react appropriately to a car is much more complicated than anticipated predators. Ideally, the complete avoidance of roads would prevent these deaths in both released and wild vervets, but a partially urbanised environment like Diani makes it impossible to do so. I suggest it might be impactful to reinforce the fear of vehicles used in the release site, but doing so will require extensive consideration of how this can be conducted without putting rehabilitation individuals at risk of injury. If possible, pre-release training that includes presenting motorised vehicles at a safe distance and pairing the presentation with an aversive stimulus may decrease vehicular deaths post-release. Alternatively, the use of video footage could be considered to teach individuals in translocation attempts the dangers of threats post-release, as previous research demonstrates that this is an effective way to influence specific behaviours in chimpanzees and other primates (Hopper 2012). This technique could be used for both biotic and abiotic training to avoid exposing released individuals to harm during training.

The combined results of this research and Donaldson's 2017 study provide a powerful, evidence-based argument for the efficacy of primate translocation. Donaldson's conclusion that the release was successful, based on the Release group demonstrating comparable survivorship to indigenous wild control groups and maintaining representative activity budgets, is directly supported by my analysis, which confirmed the success of specific pre-release methods, such as electrical wire training.

Based on this, I recommend the further use of rehabilitation release for the welfare benefit of rescued vervets. For future research, it should aim to learn what specific human factors elicit the most appropriate/inappropriate response, why, and how that can be used to train pre-release individuals regarding the threat of humans in their environment without habituation. Furthermore, understanding and perfecting this translocation protocol can serve as a detailed template to educate the conservation of non-primate species globally to assist in combating the consequences of the climate crisis.

## 4 Conclusion

In this study, I investigated the effectiveness of threat-awareness testing and training for rescued vervet monkeys by analysing their individual responses, the influence of their backgrounds and social learning, and the correlation between awareness testing and training and post-release success. This research shows that vervet response to presented threats during rehabilitation did not consistently improve across threat types and that numerous confounding factors contribute to the efficacy of rehabilitation, and the only statistically significant improvement in response across exposure was in the electrical training when Donaldson utilised an aversive stimulus alongside the presentation of a threat. Therefore, the pairing of an aversive stimulus with the presentation of a threat should be one of the primary techniques in rehabilitation threat training. While no statistically significant difference was found between captivity background or developmental stage and threat response score, the overall success of applying a threshold response score as a criterion for release (see Table 3), and the electrical wire training was evident, as their survival and threat encounter rates were comparable to wild control groups.

These findings have implications for primate rehabilitation, demonstrating that effective threat-awareness testing and training can be a viable and successful conservation strategy. Thorough future research is essential to defining a baseline of standardised pre-release methods. My thesis, for example, found that the presentation of a threat alongside a negative stimulus (electrical wire shock) was particularly effective. This specific technique could be further refined and applied to future release attempts. While not evident in this study, future research should explore the influence of individual backgrounds to provide conservationists with greater insight into how specific pre-release cases should be trained and handled. Lastly, it would be beneficial for future research to follow Release groups for a longer timeframe to fully observe the long-term impact and success of post-release groups (Sarrazin 2007, IUCN/SSC 2013).

## 5 References


Arbon, J. J., & Thornton, A. (2025). Social Learning and Culture in Mammals. In J. J. Tehrani, J. Kendal, & R. L. Kendal (Eds.), Oxford Handbook of Cultural Evolution (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198869252.013.25

Baker, Lynne R. (2002). Guidelines for Nonhuman Primate Re-introductions. Re-Introduction Specialist Group of The World Conservation Union (IUCN) Species Survival Commission (SSC).

Ballou, J. D., Lees, C., Faust, L., Long, S., Lynch, C., Bingaman Lackey, L., & Foose, T. J. (2010). Demographic and genetic management of captive populations | Request PDF. ResearchGate. https://www.researchgate.net/publication/286214677_Demographic_and_genetic_management_of_captive_populations

Banks, P. B., Carthey, A. J. R., & Bytheway, J. P. (2018). Australian native mammals recognize and respond to alien predators: A meta-analysis. Proceedings of the Royal Society B: Biological Sciences, 285(1885), 20180857. https://doi.org/10.1098/rspb.2018.0857

Banks, P. B., & Dickman, C. R. (2007). Alien predation and the effects of multiple levels of prey naiveté. Trends in Ecology & Evolution, 22(5), 229–230. https://doi.org/10.1016/j.tree.2007.02.006

Beck, B. B. (2016). The role of translocation in primate conservation. In S. A. Wich & A. J. Marshall (Eds.), An Introduction to Primate Conservation (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198703389.003.0015

Beck, B. B., Kleiman, D. G., Dietz, J. M., Castro, I., Carvalho, C., Martins, A., & Rettberg-Beck, B. (1991). Losses and reproduction in reintroduced golden lion tamarins, Leontopithecus rosalia. http://repository.si.edu/xmlui/handle/10088/3799

Beck, B. B., Rapaport, L. G., Price, M. R. S., & Wilson, A. C. (1994). Reintroduction of captive-born animals. In P. J. S. Olney, G. M. Mace, & A. T. C. Feistner (Eds.), Creative Conservation: Interactive management of wild and captive animals (pp. 265–286). Springer Netherlands. https://doi.org/10.1007/978-94-011-0721-1_13

Butynski, T.M. & De Jong, Y.A. (2022). IUCN Red List of Threatened Species: Chlorocebus pygerythrus. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en

Brakes P, Aplin L, Carroll EL,Greggor AL, Whiten A, Garland EC. (2025) Animal culture: conservation in a changing world. Phil. Trans. R. Soc. B 380: 20240127. https://doi.org/10.1098/rstb.2024.0127

Cade, T. J., & Temple, S. A. (1995). Management of threatened bird species: Evaluation of the hands-on approach. Ibis, 137(s1), S161–S172. https://doi.org/10.1111/j.1474-919X.1995.tb08438.x

Chapman, C. A., Twinomugisha, D., Teichroeb, J. A., Valenta, K., Sengupta, R., Sarkar, D., & Rothman, J. M. (2016). How Do Primates Survive Among Humans? Mechanisms Employed by Vervet Monkeys at Lake Nabugabo, Uganda. In M. T. Waller (Ed.), Ethnoprimatology: Primate Conservation in the 21st Century (pp. 77–94). Springer International Publishing. https://doi.org/10.1007/978-3-319-30469-4_5

Cheney, D. L., & Seyfarth, R. M. (1981). Selective Forces Affecting the Predator Alarm Calls of Vervet Monkeys. Behaviour, 76(1/2), 25–61.

Cheyne, S. M. (2006). Wildlife reintroduction: Considerations of habitat quality at the release site. BMC Ecology, 6(1), 5. https://doi.org/10.1186/1472-6785-6-5

Cheyne, S. M., Campbell, C. O., & Payne, K. L. (2012). Proposed guidelines for in situ gibbon rescue, rehabilitation and reintroduction. International Zoo Yearbook, 46(1), 265–281. https://doi.org/10.1111/j.1748-1090.2011.00149.x

Cremona, T., Crowther, M. S., & Webb, J. K. (2017). High mortality and small population size prevent population recovery of a reintroduced mesopredator. https://doi.org/10.1111/acv.12358

Cunneyworth, P. M. K., & Slade, A. M. (2021). Impact of Electric Shock and Electrocution on Populations of Four Monkey Species in the Suburban Town of Diani, Kenya. International Journal of Primatology, 42(2), 171–186. https://doi.org/10.1007/s10764-020-00194-z

Donaldson, A. (2017). Rehabilitation release of vervet monkeys (Chlorocebus pygerythrus hilgerti) in south coast Kenya: A Scientific Approach [Doctoral, Durham University]. https://etheses.dur.ac.uk/12295/

Dubreuil, C., Barrett, L., Henzi, P. S., Notman, H., & Pavelka, M. S. M. (2023). Age differences in the responses of vervet monkeys, Chlorocebus pygerythrus, to terrestrial alarm calls. Animal Behaviour, 201, 87–100. https://doi.org/10.1016/j.anbehav.2023.04.014

Estrada, A., Garber, P. A., Rylands, A. B., Roos, C., Fernandez-Duque, E., Fiore, A. D., Nekaris, K. A.-I., Nijman, V., Heymann, E. W., Lambert, J. E., Rovero, F., Barelli, C., Setchell, J. M., Gillespie, T. R., Mittermeier, R. A., Arregoitia, L. V., Guinea, M. de, Gouveia, S., Dobrovolski, R., … Li, B. (2017). Impending extinction crisis of the world's primates: Why primates matter. Science Advances. https://doi.org/10.1126/sciadv.1600946

Griffin, A. S., Blumstein, D. T., & Evans, C. S. (2001). Training Captive-Bred or Translocated Animals to Avoid Predators. Conservation Biology, 14(5), 1317–1326. https://doi.org/10.1046/j.1523-1739.2000.99326.x

Griffin, A. S., Evans, C. S., & Blumstein, D. T. (2001). Learning specificity in acquired predator recognition. Animal Behaviour, 62(3), 577–589. https://doi.org/10.1006/anbe.2001.1781

Griffith, B., Scott, J. M., Carpenter, J. W., & Reed, C. (1989). Translocation as a Species Conservation Tool: Status and Strategy. Science, 245(4917), 477–480. https://doi.org/10.1126/science.245.4917.477

Guy, A. J., & Curnoe, D. (2013). Guidelines for the Rehabilitation and Release of Vervet Monkeys. Primate Conservation, 27(1), 55–63. https://doi.org/10.1896/052.027.0103

Harrison RA (2024) Social learning is triggered by environmental cues in immigrant birds. PLoS Biol 22(11): e3002904. https://doi.org/10.1371/journal.pbio.3002904

Hopper, L. M., Lambeth, S. P., & Schapiro, S. J. (2012). An evaluation of the efficacy of video displays for use with chimpanzees (Pan troglodytes). American Journal of Primatology, 74(5), 442–449. https://doi.org/10.1002/ajp.22001

Isbell, L. A., & Etting, S. F. (2017). Scales drive detection, attention, and memory of snakes in wild vervet monkeys (Chlorocebus pygerythrus). Primates, 58(1), 121–129. https://doi.org/10.1007/s10329-016-0562-y

IUCN. (1987). The IUCN position statement on translocation of living organisms: Introductions, re-introductions and re-stocking. IUCN. https://portals.iucn.org/library/node/6507

Junker, J., Kühl, H. S., Orth, L., Smith, R. K., Petrovan, S. O., & Sutherland, W. J. (2020). 7. PRIMATE CONSERVATION. 431–482. https://doi.org/10.11647/obp.0191.07

Kendal, R. L., Boogert, N. J., Rendell, L., Laland, K. N., Webster, M., & Jones, P. L. (2018). Social Learning Strategies: Bridge-Building between Fields. Trends in Cognitive Sciences, 22(7), 651–665. https://doi.org/10.1016/j.tics.2018.04.003

Khan. (2025). Impact of captivity on social bahaviour of Chimpanzee (Pan troglodytes) | Request PDF. ResearchGate. https://www.researchgate.net/publication/286202559_Impact_of_captivity_on_social_bahaviour_of_Chimpanzee_Pan_troglodytes

Kierulff, M. C. M., Ruiz-Miranda, C. R., de Oliveira, P. P., Beck, B. B., Martins, A., Dietz, J. M., Rambaldi, D. M., & Baker, A. J. (2012). The Golden lion tamarin rosalia: A conservation success story. International Zoo Yearbook, 46(1), 36–45. https://doi.org/10.1111/j.1748-1090.2012.00170.x

Kirkwood, J. (2013). Guidelines for reintroductions and other conservation translocations. Animal Welfare, 22(4), 489–490. https://doi.org/10.1017/S0962728600005637

Lingle, S., Feldman, A., Boyce, M. S., & Wilson, W. F. (2008). Prey Behavior, Age-Dependent Vulnerability, and Predation Rates. The American Naturalist, 172(5), 712–725. https://doi.org/10.1086/591675

Lutz, C. K., & Novak, M. A. (2005). Environmental enrichment for nonhuman primates: Theory and application. ILAR Journal, 46(2), 178–191. https://doi.org/10.1093/ilar.46.2.178

Mallapur, A., & Choudhury, B. C. (2003). Behavioral Abnormalities in Captive Nonhuman Primates. Journal of Applied Animal Welfare Science. https://doi.org/10.1207/s15327604jaws0604_2

McAdam, J. (2010). Climate Change and Displacement: Multidisciplinary Perspectives. Bloomsbury Publishing.

McElvaney TJ, Osman M, Mareschal I (2021) Perceiving threat in others: The role of body morphology. PLoS ONE 16(4): e0249782. https://doi.org/10.1371/journal.pone.0249782

Mittermeier, R.A., Reuter, K.E., Rylands, A.B., Ang, A., Jerusalinsky, L., Nash, S.D., Schwitzer, C., Ratsimbazafy, J. and Humle, T. (eds.). 2024. Primates in Peril: The World's 25 Most Endangered Primates 2023–2025. IUCN SSC Primate Specialist Group, International Primatological Society, Re:wild, Washington, DC. 155pp

Mikula, P., Šaffa, G., Nelson, E., & Tryjanowski, P. (2018). Risk perception of vervet monkeys Chlorocebus pygerythrus to humans in urban and rural environments. Behavioural Processes, 147, 21–27. https://doi.org/10.1016/j.beproc.2017.12.011

Mineka, S., & Cook, M. (1993). Mechanisms involved in the observational conditioning of fear. Journal of experimental psychology. General, 122(1), 23–38. https://doi.org/10.1037//0096-3445.122.1.23

Mirza, R. S., & Chivers, D. P. (2000). Predator-recognition training enhances survival of brook trout: Evidence from laboratory and field-enclosure studies. Canadian Journal of Zoology, 78(12), 2198–2208. https://doi.org/10.1139/z00-164

Pavlov (1927), P. I. (2010). Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex. Annals of Neurosciences, 17(3), 136–141. https://doi.org/10.5214/ans.0972-7531.1017309

Riedler, B., Millesi, E., & Pratje, P. H. (2010). Adaptation to Forest Life During the Reintroduction Process of Immature Pongo abelii. International Journal of Primatology, 31(4), 647–663. https://doi.org/10.1007/s10764-010-9418-2

Ruiz-Miranda, Carlos, Beck, Benjamin, & Kleiman, Devra. (2010). Re-introduction and translocation of golden lion tamarins, Atlantic Coastal Forest, Brazil: The creation of a metapopulation. IUCN SSC Conservation Translocation Specialist Group. https://iucn-ctsg.org/publication/re-introduction-and-translocation-of-golden-lion-tamarins-at/

San Diego Zoo Wildlife Alliance. (n.d.). Vervet Monkey | San Diego Zoo Animals & Plants. Retrieved July 27, 2025, from https://animals.sandiegozoo.org/animals/vervet-monkey

Sarrazin, François (2007). "Introductory remarks" Ecoscience 14 (4). https://doi.org/10.2980/1195-6860(2007)14[iv:IR]2.0.CO;2

Schad, L., van de Waal, E., & Fischer, J. (2025). Anti-Snake Behavior and Snake Discrimination in Vervet Monkeys. Ethology, 131(3), e13541. https://doi.org/10.1111/eth.13541

Seyfarth, R. M., & Cheney, D. L. (2003). Signalers and receivers in animal communication. Annual Review of Psychology, 54, 145–173. https://doi.org/10.1146/annurev.psych.54.101601.145121

Seyfarth, R. M., Cheney, D. L., & Marler, P. (1980a). Monkey responses to three different alarm calls: Evidence of predator classification and semantic communication. Science (New York, N.Y.), 210(4471), 801–803. https://doi.org/10.1126/science.7433999

Seyfarth, R. M., Cheney, D. L., & Marler, P. (1980b). Vervet monkey alarm calls: Semantic communication in a free-ranging primate. Animal Behaviour, 28(4), 1070–1094. https://doi.org/10.1016/S0003-3472(80)80097-2

Shier, D. M., & Owings, D. H. (2007). Effects of social learning on predator training and postrelease survival in juvenile black-tailed prairie dogs, Cynomys ludovicianus. Animal Behaviour, 73(4), 567–577. https://doi.org/10.1016/j.anbehav.2006.09.009

Stoinski, T. S., Beck, B. B., Bloomsmith, M. A., & Maple, T. L. (2003). A Behavioral Comparison of Captive-Born, Reintroduced Golden Lion Tamarins and Their Wild-Born Offspring. Behaviour, 140(2), 137–160.

Struhsaker, T. T. (1967). Social Structure Among Vervet Monkeys (Cercopithecus Aethiops). https://doi.org/10.1163/156853967X00073

Torres-Romero, E. J., Nijman, V., Fernández, D., & Eppley, T. M. (2023). Human-modified landscapes driving the global primate extinction crisis. Global Change Biology, 29(20), 5775–5787. https://doi.org/10.1111/gcb.16902

Tutin, C. E. G., Ancrenaz, M., Paredes, J., Vacher-Vallas, M., Vidal, C., Goossens, B., Bruford, M. W., & Jamart, A. (2008). Conservation Biology Framework for the Release of Wild-Born Orphaned Chimpanzees into the Conkouati Reserve, Congo. Conservation Biology, 15(5), 1247–1257. https://doi.org/10.1111/j.1523-1739.2001.00046.x

van de Waal, E., Claidière, N., & Whiten, A. (2013). Social learning and spread of alternative means of opening an artificial fruit in four groups of vervet monkeys. Animal Behaviour, 85(1), 71–76. https://doi.org/10.1016/j.anbehav.2012.10.008

van de Waal, E., Renevey, N., Favre, C. M., & Bshary, R. (2010). Selective attention to philopatric models causes directed social learning in wild vervet monkeys. Proceedings. Biological Sciences, 277(1691), 2105–2111. https://doi.org/10.1098/rspb.2009.2260

Warren, K. S., Verschoor, E. J., Langenhuijzen, S., Heriyanto, Swan, R. A., Vigilant, L., & Heeney, J. L. (2001). Speciation and Intrasubspecific Variation of Bornean Orangutans, Pongo pygmaeus pygmaeus. Molecular Biology and Evolution, 18(4), 472–480. https://doi.org/10.1093/oxfordjournals.molbev.a003826

Whiten, A., & van de Waal, E. (2018). The pervasive role of social learning in primate lifetime development. Behavioral ecology and sociobiology, 72(5), 80. https://doi.org/10.1007/s00265-018-2489-3