Differences in stress levels between wild-caught and captive born Asian elephants

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Wild capture of animals remains, among other uses, important for maintaining genetically healthy and viable captive populations. The capture process is often very stressful and potentially risky, with potentially far-reaching and long-term effects on the health and welfare of the captured animals such as increased mortality and lowered fertility. This thesis aims to shed light into the underlying physiological factors behind such issues, as shown in previous studies on wild-caught Asian elephants (*Elephas maximus*) that are used as labour in Myanmar timber camps. This was done by analysing data collected from elephant faecal samples and measuring the concentrations of faecal glucocorticoid metabolites (FGM) in them. Results showed seasonal variation of FGM concentrations, with FGM concentrations being higher in the hot season compared to the cold season. Furthermore, the age of the elephants from the studied population had significant effects on their FGM concentrations with retired elephants having lower FGM concentrations than working elephants or elephants in training and elephants in training showing the highest FGM concentrations. However, whether the elephants were wild-caught, or captive born did not show significant effects in the analysed data. Harmful stress-related long-term effects were not found by this study, although the limited scope of the study combined with comparisons to previous studies means their existence cannot be ruled out completely. Further research into elephant stressors and stress hormone levels using a broader group of potentially significant factors is therefore advised.

Key words: *Elephas maximus*; elephant age; faecal glucocorticoid metabolites; seasonal variation; stress; wild capture

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1 Introduction

Human encroachment on the natural world for resource exploitation and living space is causing great pressure on ecosystems and their animal populations, threatening global biodiversity. Significant numbers of individuals from endangered species are currently held in various degrees of captivity for reasons both benevolent and exploitative (*Mason 2010)*. These reasons to keep animals in captivity range from livestock, pet keeping and entertainment purposes to scientific research and conservation efforts. Zoos constitute a grey area between pro-animal and pro-human sides of animal captivity, largely varying from one zoo to another, depending on their quality and ethos. For altruistic intentions like conservation efforts or more selfish, human-centric ones like labour, creating and maintaining captive populations presents an additional burden on often already imperilled wild populations.

Elephant populations have declined in a drastic and worrying manner in the past decades due to habitat fragmentation, poaching and -most notable for this study- from capture of wild individuals into captivity. Up to a third of the remaining Asian elephants (*Elephas maximus*) worldwide now live in captivity or semi-captivity as working animals, in zoos, or in sanctuaries (*Jackson et al. 2019*). These captive populations of elephants are currently not self-sustainable, so wild populations are used as a source for new captives. From the point of view of both conservation and ethics, this is far from an ideal solution; wild elephant populations face serious problems even without this drain of individuals (*Leimgruber et al. 2011*).

Elephants are large animals, making their capture and transportation stressful, with many potential risks for injuries, capture myopathy or other complications (*Arnemo et al. 2006*). They are also a very intelligent and social species, and so capturing individuals from the wild and from their family herds will likely lead to negative effects such as stress or decreased health. In many species, such as marine mammals and primates (*Blank et al. 1983; Harcourt et al. 2010*), stress resulting from capture appears to have consequences for the health, behaviour, and life-history of animals in the short-term, though long-term effects remain largely unknown. Since capturing elephants from the wild to bolster captive populations presents ecological and ethical issues, it is important to improve the well-being, life quality and birth success of captive elephants to make the captive populations more self-sustaining (*Leimgruber et al. 2011; Jackson et al. 2019*). This would reduce the need to capture elephants from the wild.

In Myanmar, Asian elephants are used in the timber logging industry, which is vital to the livelihoods of many Myanmar people. The country has the largest captive population of elephants in the world at roughly 5000 individuals, and still holds large quantities of habitat area suitable for elephants, even if these habitats are under threat of diminishing and only a small percentage of them are protected (*Leimgruber et al. 2011*). While elephants used in the timber industry face exertion and stress from being put to work, their workload and hours are strictly regulated by the Myanmar government. Timber elephants are released to forests outside of working hours and have holidays and maternity leave (*Zaw 1997; Toke Gale 1971*). These elephants therefore have access to their natural habitats, especially when compared to elephants living in zoos or other more restrictive captive conditions. Consequently, the semi-captive timber elephant population has mortality and fertility levels closer to natural ones than captive ones in zoos (*Clubb. et al. 2008*). Nevertheless, the semi-captive population remains unsustainable without capture of wild-caught individuals, and the wild elephant population of Myanmar could eventually face extinction unless the timber elephant population can be made self-sustainable (*Jackson et al. 2019*).

While captive born elephants avoid the stressful event of being abducted from the wild, the four week-long taming process that captive born calves undergo - where they are separated from their mothers and allomothers - is still a stressful experience for them. However, the taming of wild-captured elephants is likely even more stressful since the captive born calves are at least used to human presence from birth (*Crawley et al. 2020*). Not all differences between captive and wild conditions promote increased stress, however; regular de-worming and other veterinary care provide health benefits not available to truly wild elephants (*Dos Santos et al. 2020*). This means that while both the capture and taming processes are very stressful to elephants, their semi-captive living conditions also provide some stress-relieving benefits without the worst stressors of captivity, at least if they are properly treated by humans.

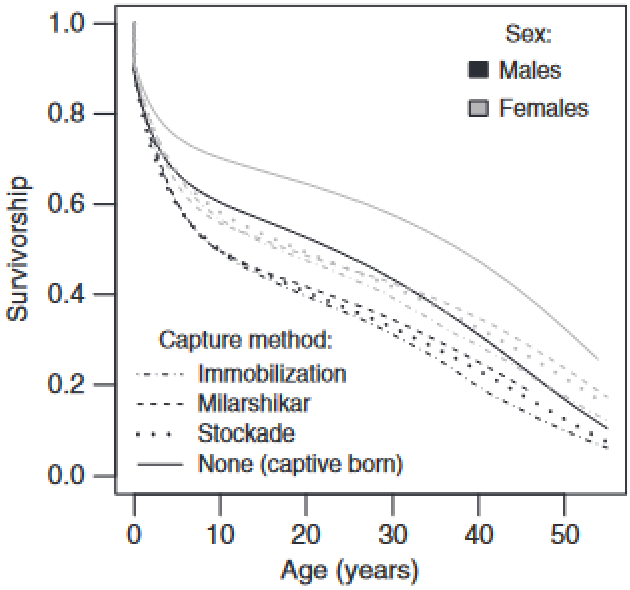

Figure 1. Overall impacts of capture and sex on elephant survival in Myanmar. The figure showcases the increased mortality of wild-caught elephants (with three different capture methods) in comparison to captive born ones. The figure has been reproduced from Lahdenperä et al. 2018 with permission.

Previous studies demonstrate that capture from the wild can have detrimental consequences on elephant survival and reproduction (*Lahdenperä et al. 2018; Lahdenperä et al. 2019, Figure 1*). Such evidence shows wild-caught individuals having reduced survival and reproduction levels over a decade when compared to captive born timber industry elephants, at least in Myanmar. These negative effects even hold significant influence over the next generation, with reduced survival of offspring up to the age of 5, according to *Lahdenperä et al.* (2019). However, underlying reasons for these severe life history effects are still unknown, although it has been speculated that they are due to increased stress levels and changes in health due to capture from the wild, leading to reductions in their survival and reproductive rates in subsequent months and years. In their 2018 study, Lahdenperä and colleagues found that differences in how individual elephants experience the taming process affected their median lifespan, and that older individuals experienced worse consequences from capture. They went on to point out that the results for both fertility and survival effects also have previous evidence from limited studies in other species, such as killer whales (*Jett & Vendre 2015*) and macaques (*Ha et al. 2000*).

While many studies on differences between wild-caught and captive born animals have already been made, few have studied what capturing and captivity do to the mental and physical health of animals, especially in the long-term. In a study by *Jones et al. (2005)*, Tasmanian devils (*Sarcophilus harrisii*) showed increased concentrations of plasma cortisol after capture and transfer into captivity, but these levels decreased during the 6 months following capture to normal levels, indicating the absence of chronic stress after acclimation to captivity. Captured degus (*Octodon degus*) exhibited higher cortisol stress responses in laboratory conditions even after long periods of acclimatisation, but the response to human-manipulated stress events was still notably higher among captive born individuals than wild ones (*Quispe et al. 2013*). Chronic captivity stress appears to differ from one species to another, as argued by *Fischer & Romero (2019)*. Why some species adapt to captivity better than others remains unknown and requires further research *(Mason 2010*).

The purpose of the present thesis is to investigate in closer detail the underlying physiological causes potentially leading to higher mortality and lower reproductive success of wild-caught Asian elephants in captivity. This can be achieved by looking at their cortisol levels to measure the amount of stress and see if elephants from different origins exhibit significant differences in their stress hormone levels. Cortisol is a steroid hormone which helps regulate the body's responses to stress. In non-rodent mammals, glucocorticoid cortisol has many different functions, among them cardiovascular health, metabolic processes, and the effectiveness of immune responses (*Broom 2017*). When higher levels of cortisol in the body become a chronic issue, they can have various adverse effects on the individual's health, such as weakening of the immune system or decreased fertility.

The working hypothesis for the present thesis is that wild captured animals have lower body condition because of stress, and thus exhibit higher stress hormone levels because of capture from the wild. The aim is to compare cortisol measures (or more exact faecal glucocorticoid metabolite (FGM) concentrations) between wild-captured and captive born elephants and shed more light on both the short and long-term effects of capture from the wild have on elephants, a topic which has rarely been studied in long-lived highly social animals.

2 Materials & Methods

Data for this thesis comes from long-term research conducted by the Myanmar Timber Elephant Project of the University of Turku on Myanma Timber Enterprise / Myanmar government-owned logging elephants employed in Myanmar. This includes demographic data on age, sex, origin (captive born or wild-caught) and other life-history information, collected originally by local veterinarians as part of their work and reporting to the government and detailed in elephant logbooks and annual extraction reports. In this thesis I combine this information with faecal cortisol data collected by the project since 2011 on research elephants in the Sagaing region of northern Myanmar (*Seltmann et al. 2022*).

2.1 Study population

The Asian elephants used in my study work as draft animals and transportation in the Myanmar timber logging industry, owned by the governmental institution Myanma Timber Enterprise (MTE) which keeps detailed logbooks on all their 3000+ semi-captive elephants. Each elephant's individual logbook records their life history through information such as origin (wild-caught (WC)/captive born (CB)), birth date, sex, offspring, which personal handler (mahout) they are assigned with, and any required veterinary aid. These data points are recorded monthly by veterinarians. (*Crawley et al. 2020*) Such detailed long-term record-keeping is a great benefit for scientific research on the species and how these elephants fare in their semi-captive conditions compared to their wild or fully captive relatives.

Working season of adults takes place between June and February, utilising the monsoon season and cooler winter months. Juvenile elephants in training (ages 5-17) as well as mother elephants after their maternity leave of 2 years are also utilized for light work. (*Crawley et al. 2020*) At the age of 55 all elephants are retired from the workforce but kept and looked after in retirement camps until death. Calves are raised by their mothers and allomothers but separated for taming at the age of 4 or 5, a process which can be very stressful for the calf (*Crawley et al. 2021*). During the nights and off-time, the elephants breed and forage for food without human oversight, interacting freely with other semi-captive but also wild elephants. Hence, the population's definition as semi-captive rather than fully captive. Artificial changes to reproduction rate or methods do not seem to exist, unlike in many zoo elephants. (*Lahdenperä et al. 2019*)

Wild capture usually takes place during the cool season and is achieved through three alternative methods: immobilization (sedation) and *milarshikar* (lassoing) when capturing individuals, and stockade for capturing groups. Immobilization and *milarshikar* target one individual at a time, whereas stockades are used for capturing several individuals at once (*Lair 1997; Lahdenperä et al. 2019*) While the government of Myanmar did formally ban the capture of wild elephants in the 1990s, the practice still happens on a smaller scale, both because of human-elephant conflicts and in the form of illegal capture. Length of the taming process following capture depends on the ages and personalities of individual elephants, with older elephants usually requiring a lengthier process to break in. Taming process is, especially in the first few days, very stressful for the elephants, with mortality rates estimated by the government ranging between 5 and 30%, most of the deaths occurring in the months soon after capture (*Lair 1997; Lahdenperä et al. 2019)*.

2.2 Faecal glucocorticoid metabolites

The FGM data used in the present study consisted of 3757 total observations from 335 individual elephants, among which 202 female elephants were present in comparison to 133 males, leading to an obvious sex imbalance within the sample group, and was similar in both origins (for captive born 133 females to 104 males, for wild-caught 69 females to 29 males). Captive born elephants are present in greater numbers in the population than wild-caught ones (Crawley et al. 2021), with roughly 75 % being presently captive born and 25% wild-caught. All elephants under 10 years old were excluded from the sample group owing to a lack of suitable data for wild-caught individuals in that age group. Wild-caught elephants had a higher median age (median 50 years, mean 49 years, ranging between 10-71 years of age) than captive born elephants (median 16 years, mean 26 years, ranging from 10-67 years of age), and were also fewer in number at 98 wild-caught individuals compared to 237 captive born ones.

Faecal glucocorticoid metabolite samples used in this study were collected between 2011 and 2018 (the author was not involved in collecting or laboratory analysis of the samples), and their laboratory analysis was conducted between August 2014 and October 2019. A protocol for boiling extraction, as well as an enzyme immunoassay (EIA) suitable for glucocorticoid metabolites (*Watson et al. 2013*) were used for gathering glucocorticoid metabolites from the elephant faecal samples. Nunc MaxiSorp® plates, room temperature substrate reagents and dark incubation conditions were utilised to optimise the original EIA protocol. Measure season for the FGM samples was determined via the records kept of the measure months, and only samples from individual elephants that had recorded data were used (*Ukonaho 2019*).

Double-antibody enzyme immunoassay (EIA) had been used to determine concentrations of FGMs in the data. The used EIA relied on a polyclonal rabbit anti-corticosterone antibody CJM006 but had been validated for Asian elephants. Samples preserved in 5 ml of 90% ethanol were extracted through boiling and then centrifuged. Vortexing the samples for one minute in 3ml of ethanol, drying them a second time and then resuspending them in 3 ml of methanol was then done to reconstitute the samples. Extracts were diluted in phosphate buffer and stored in -20 degrees Celsius to await analysis. Second antibody-coated plates were made by adding anti-rabbit IgG to wells in a microtiter plate and incubating at room temperature for 15-24 hours. Following the incubation period, the wells were emptied, blotted, and dried using a Sanpla Dry Keeper with some loose desiccant at its bottom.

2.3 Statistical analysis

My main interest was to determine whether elephant origin – whether they were wild-caught, or captive born – was associated with their faecal glucocorticoid metabolite concentration, therefore FGM concentration was included as the response variable. The elephants in my sample were of different ages and sexes and the samples were collected during different seasons, variables that are potentially associated with stress level variation. Therefore, my statistical models also controlled for variation in these sources. In the models, season was included as categorical variable. Samples collected in October–February were categorised to cold-season, March–May to hot-season and June–September to monsoon-season. Furthermore, age categories were used in the models instead of a continuous variable due to uneven distribution of ages across the sampled animals. Training-group included all elephants between ages 10-18 at sample collection, working-group elephants between ages 19-54 and retired elephants between ages 55-71. All statistical analyses were conducted with R version 4.2.2 (*R Core Team, 2022*), using packages *tidyverse* (*Wickham et al. 2019*), *lme4* (*Bates et al. 2015*), and *emmeans* (*Lenth, 2023*). To find out which of the four chosen explanatory variables (origin, sex, season, age) were significant, I used several approaches. I first built generalized linear mixed models (GLMMs) with gamma error distribution fitted with Laplace Approximation and individual identity as the random factor. In addition, I log-transformed my response variable FGM concentration, so the variable would be normally distributed. I then ran linear mixed models (LMMs) fitted using restricted maximum likelihood and individual identity as the random factor.

As a first step I ran univariate models, only including one explanatory variable at a time for each GLMM and LMM (hence eight models altogether). Following that, I combined all variables into a GLMM starting model with gamma error distribution fitted with Laplace Approximation and individual identity as the random factor and began stepwise backwards model selection, always removing the least p-value significant variable at each step. The level of significance was set at p value < 0.05. Sex was the first to be removed, followed by origin. The final model included sample season and age as the variables significantly related to FGM concentrations. To find out differences between the different levels of those categorical variables, I ran post-hoc tests using the package *emmeans*.

3 Results

Overall, wild-caught elephants showed a shorter range of FGM concentrations and slightly smaller FGM concentrations (minimum: 10.58 ng/g; maximum: 314.46 n/g; mean: 65.70 ng/g) than captive born elephants (minimum: 5.97 ng/g; maximum: 356.36 n/g; mean: 72.03 ng/g).

Differences in origin were only significant in univariate models (*Table 1 and 2*), but not statistically significant in the full model adjusted for other variables (*Table 3*). In addition, I found no evidence for a difference in FGM concentrations between male and female elephants in univariate or the multivariate models (*Tables 1 – 3; Figure 3*). Furthermore, the season in which sampling took place and the age of the elephants sampled were the only studied variables that proved to be significantly associated with FGM concentrations in all uni- and multivariate models (*Tables 1 – 3*).

In detail, the mean FGM concentration was 69.41 during monsoon, 68.86 ng/g during cold season and 73.86 ng/g during hot season, and season had a statistically significant effect on FGM concentrations (*Table 4; Figures 4 and 6*), with the cold-season being statistically different from the hot-season season (*Table 4*). Elephants in training had the highest mean FGM concentrations (74.53 ng/g) *(Table 5; Figures 5 and 7)*, followed by working elephants (66.86 ng/g) and retired elephants (70.49 ng/g) with the lowest FGM concentrations. Looking at the mean FGM concentrations of working and retired elephants (see also Fig. 2), it seems that retired individuals would have higher FGM concentrations compared to working elephants. This is opposed to the findings of the post-hoc test (see Table 5), where retired elephants have lower FGM concentrations compared to working individuals. This can be explained that the mean values above are from the raw data (see also Fig. 5 where raw data was used for plotting) and not from the final multivariate model, where effects of season have been accounted for. Therefore, the result stand that training elephants have higher FGM concentrations compared to working and retired elephants, and working elephants have higher FGM concentrations compared to retired elephants (*Table 5*). Retired elephants and training elephants were the two age groups that showed the largest differences in FGM concentrations between one another (*Table 5*).

Table 1. Results from the four different univariate GLMMs with estimates, standard deviation errors (SD), t-values (*t*), and *p*-values.

Univariate model	**Explanatory variable**	**Estimate**	**SD**	***t***	***p*-value**
I	Origin	-0.12	0.05	-2.56	0.011
II	Sex	0.05	0.04	1.18	0.24
III	Hot season	0.04	0.02	2.51	0.012
III	Monsoon season	0.01	0.02	0.83	0.408
IV	Age category – training	0.34	0.07	5.12	<0.01
IV	Age category – working	0.15	0.06	2.63	0.008

Table 2. Results from the four different univariate LMMs with estimates, standard deviation errors (SD), degrees of freedom (DF). *t*-values (*t*) and p-values.

Univariate model	**Explanatory variable**	**Estimate**	**SD**	**DF**	***t***	***p*-value**
I	origin	-0.10	0.04	333	-2.74	0.007
II	sex	0.03	0.03	3421	0.90	0.37
III	hot season	0.03	0.02	3420	1.75	0.081
III	monsoon season	0.00	0.02	3420	0.22	0.826
IV	age category - training	0.23	0.05	3420	4.53	<.0001
IV	age category - working	0.06	0.04	3420	1.27	0.21

Table 3. Results from stepwise backwords model selection on GLMMs with all four explanatory variables in the starting model. Non-significant variables (origin and sex) are from their specific models but shown here together with final model including only significant variables (season and age). Included are estimates, standard deviation errors (SD), t-values and p-values.

explanatory variable	estimate	standard deviation error	t-value	p-value
origin	-0.03	0.05	-0.57	0.57
sex	0.00	0.04	0.05	0.96
hot season	0.04	0.02	2.52	0.01
monsoon season	0.02	0.02	1.00	0.32
age category – training	0.34	0.07	5.11	<0.01
age category – working	0.14	0.06	2.61	0.01

Table 4. Results from post hoc-tests using emmeans to compare the three categories of seasons involved (hot, cold and monsoon), with estimates, standard errors (SE), z ratios and p-values.

Contrast	estimate	SE	z ratio	p-value
cold – hot	-0.04	0.02	-2.52	0.031
cold – monsoon	-0.02	0.02	-1.00	0.58
hot – monsoon	0.03	0.02	1.49	0.296

Table 5. Results from post hoc tests using emmeans for comparisons of the three age categories; training (10-18), working (19-54) and retired (55-71). Included are estimates, standard errors (SE), z ratios and p-values.

Contrast	estimate	SE	z ratio	p-value
retired – training	-0.34	0.07	-5.11	<.0001
retired – working	-0.14	0.06	-2.61	0.0244
training – working	0.19	0.04	4.55	<.0001

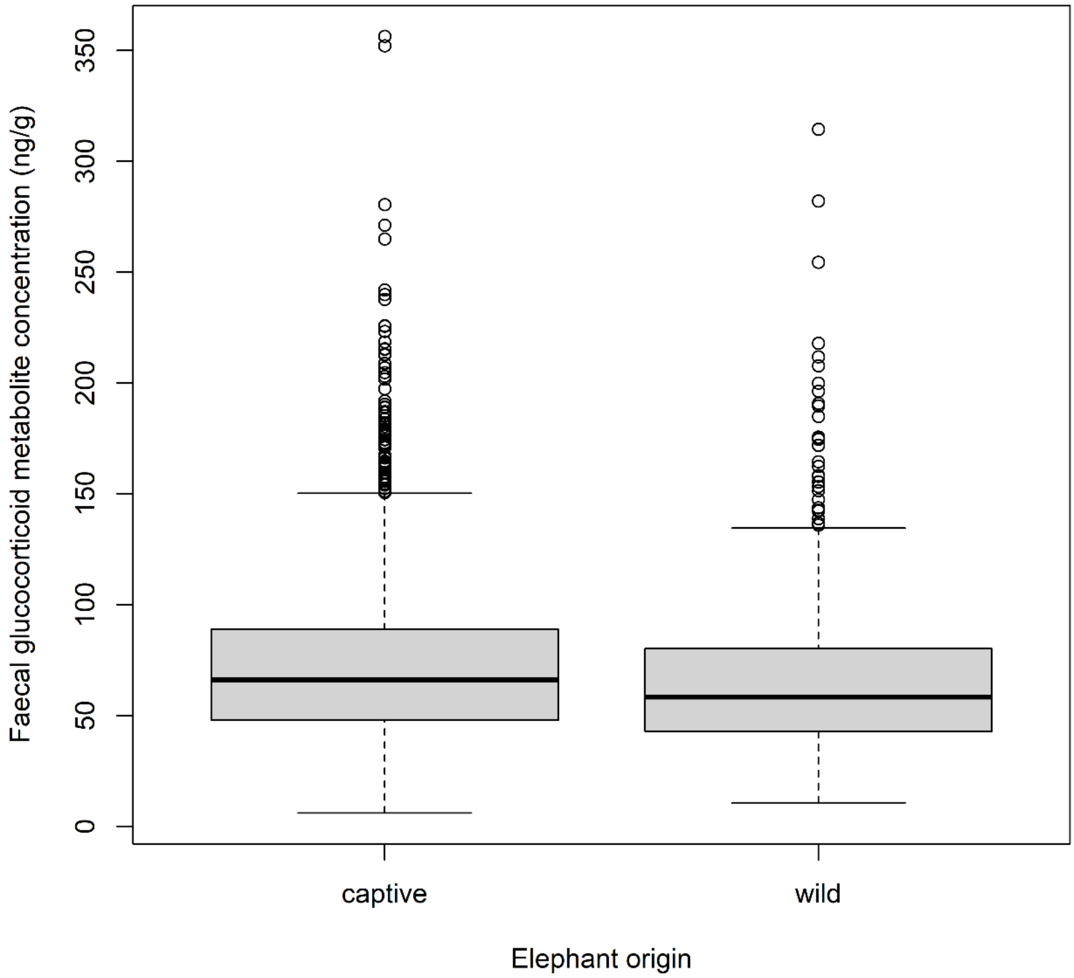

Figure 2: Comparison of FGM concentrations in studied elephants by their origin. Black horizontal lines are the raw means (Using Seltmann et al. 2022 as a guideline) and the dots/circles represent raw data points. Captive born elephants appear to have slightly higher concentrations than the wild ones do, though not significantly so.

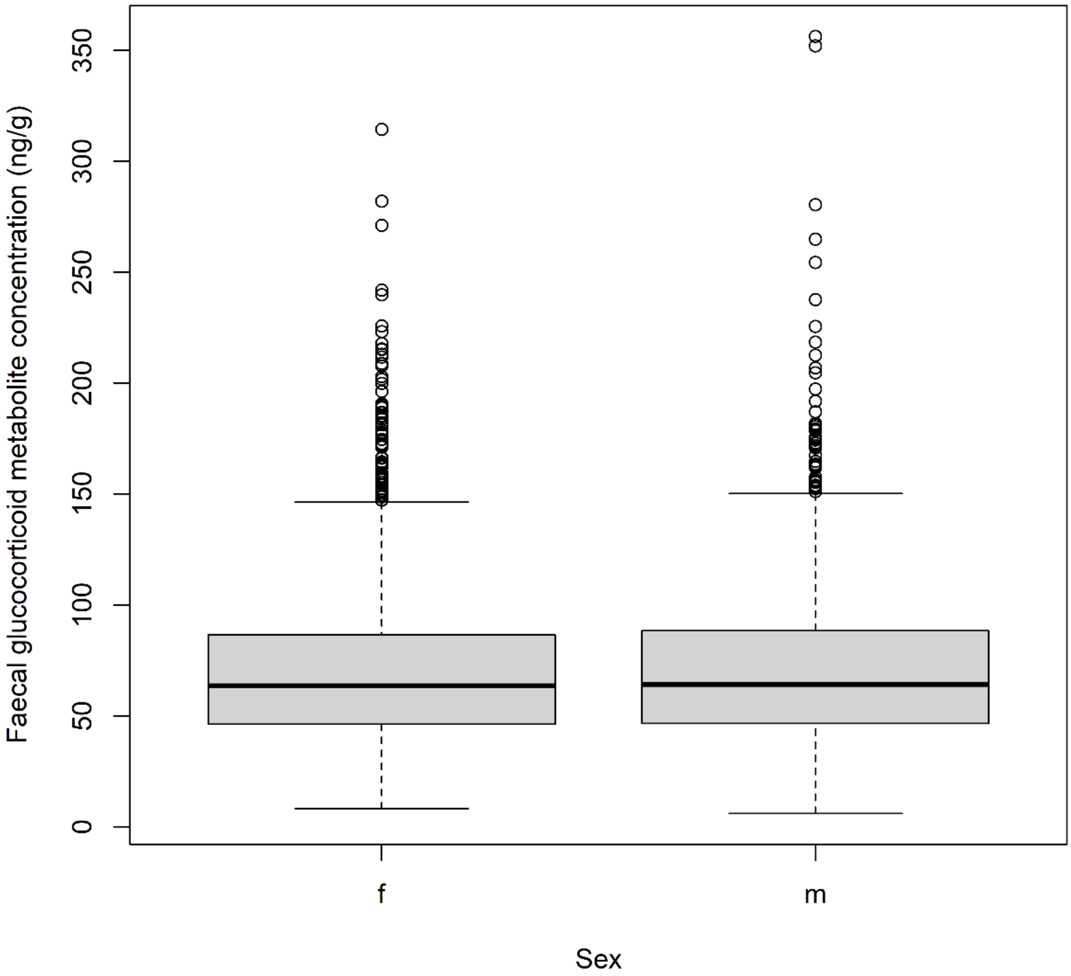

Figure 3: Comparison of FGM concentrations in studied elephants by sex. f denotes females and m males. Black horizontal lines are the raw means and the dots/circles represent raw data points. No significant differences that would affect FGM-concentrations were found.

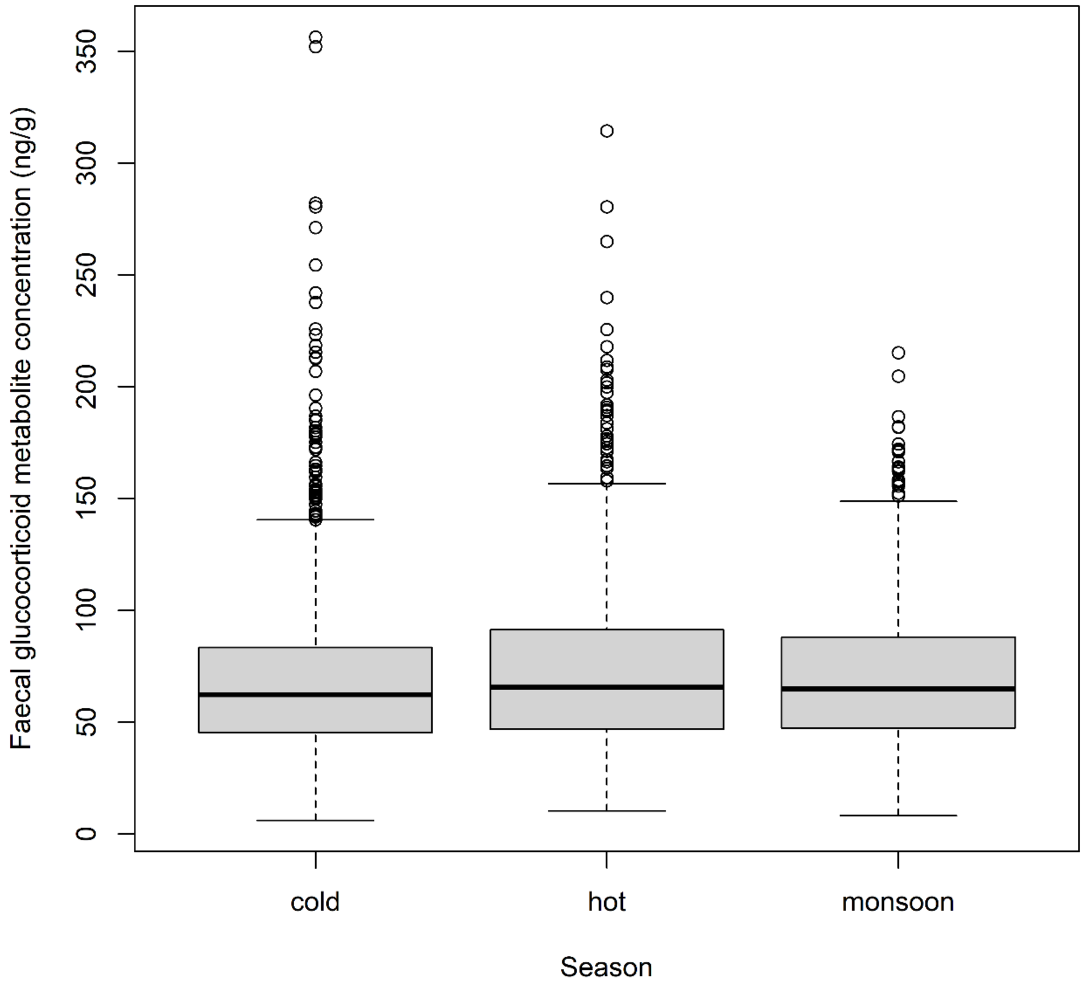

Figure 4: Comparison of FGM concentrations in studied elephants according to their sampling season (cold, hot, monsoon). Black horizontal lines are the raw means, and the dots/circles represent raw data points. FGM values increased significantly during the hot season (p=0.031, Table 4).

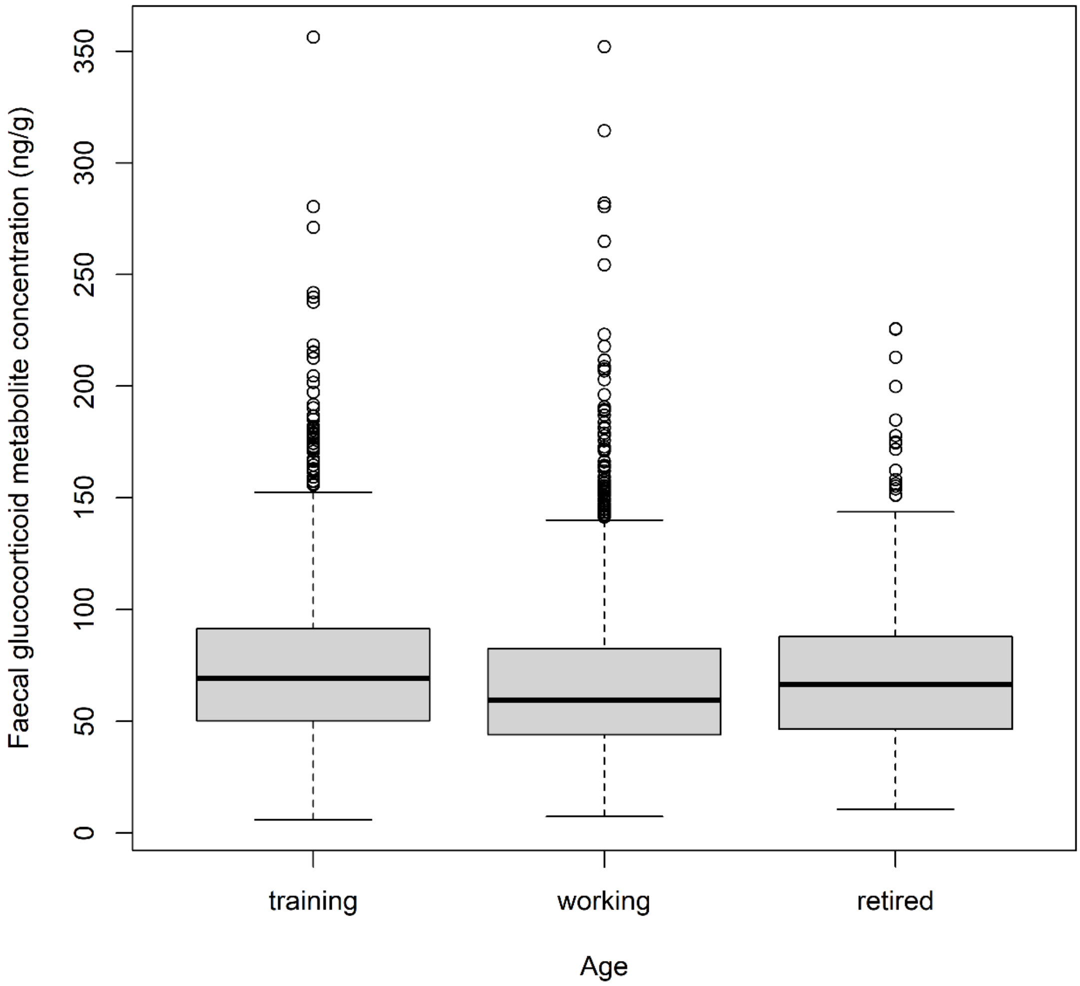

Figure 5: Comparison of FGM concentrations in studied elephants according to their age category. Black horizontal lines are the raw means, and the dots/circles represent raw data points. Elephants undergoing training displayed the highest cortisol levels, though the differences to working elephants were not very large, while retired individuals had the lowest levels and displayed a smaller range of variation.

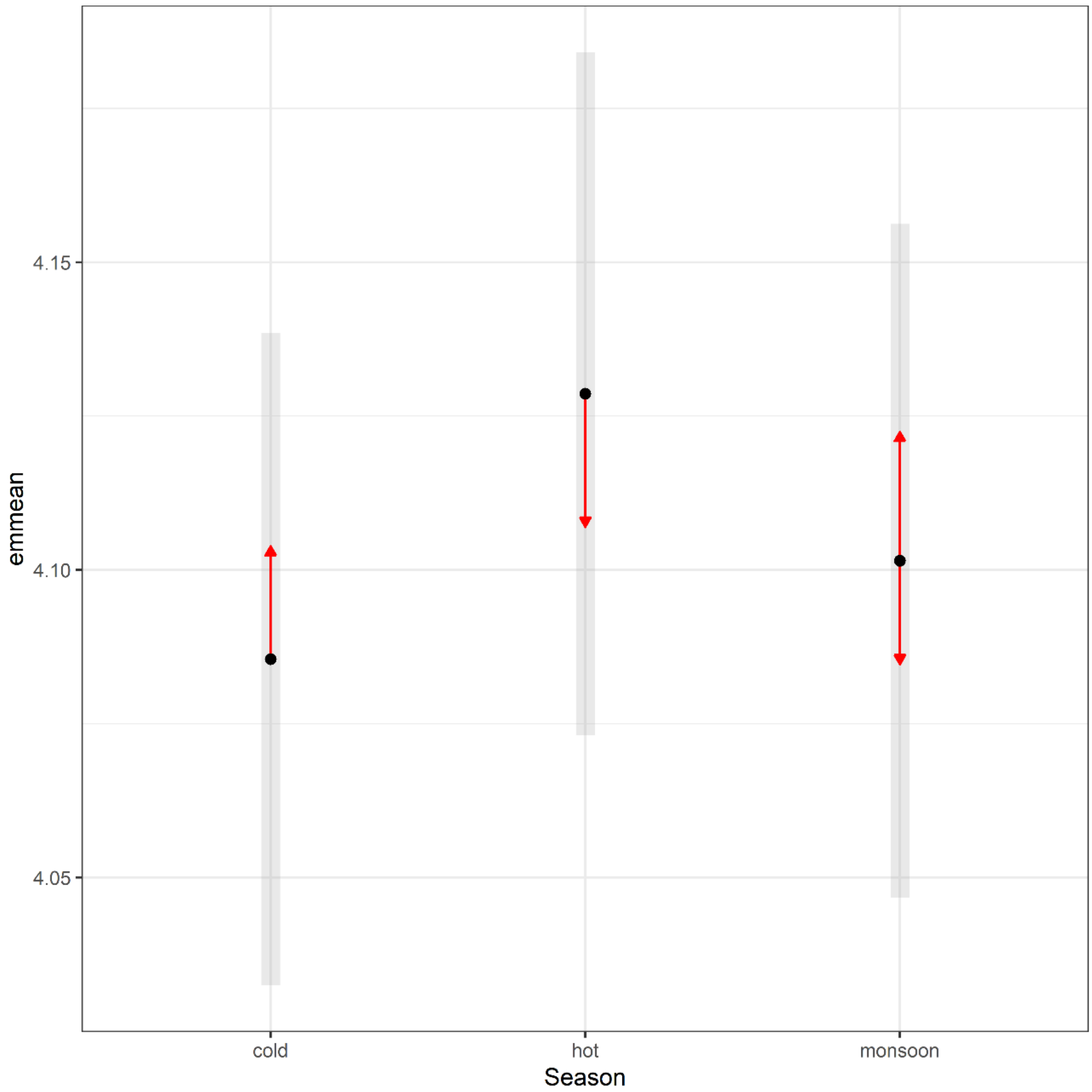

Fig 6. Post-hoc comparisons of estimated marginal means of FGM concentrations of the three different seasons. When the red arrows overlap then there is no significant difference between the groups.

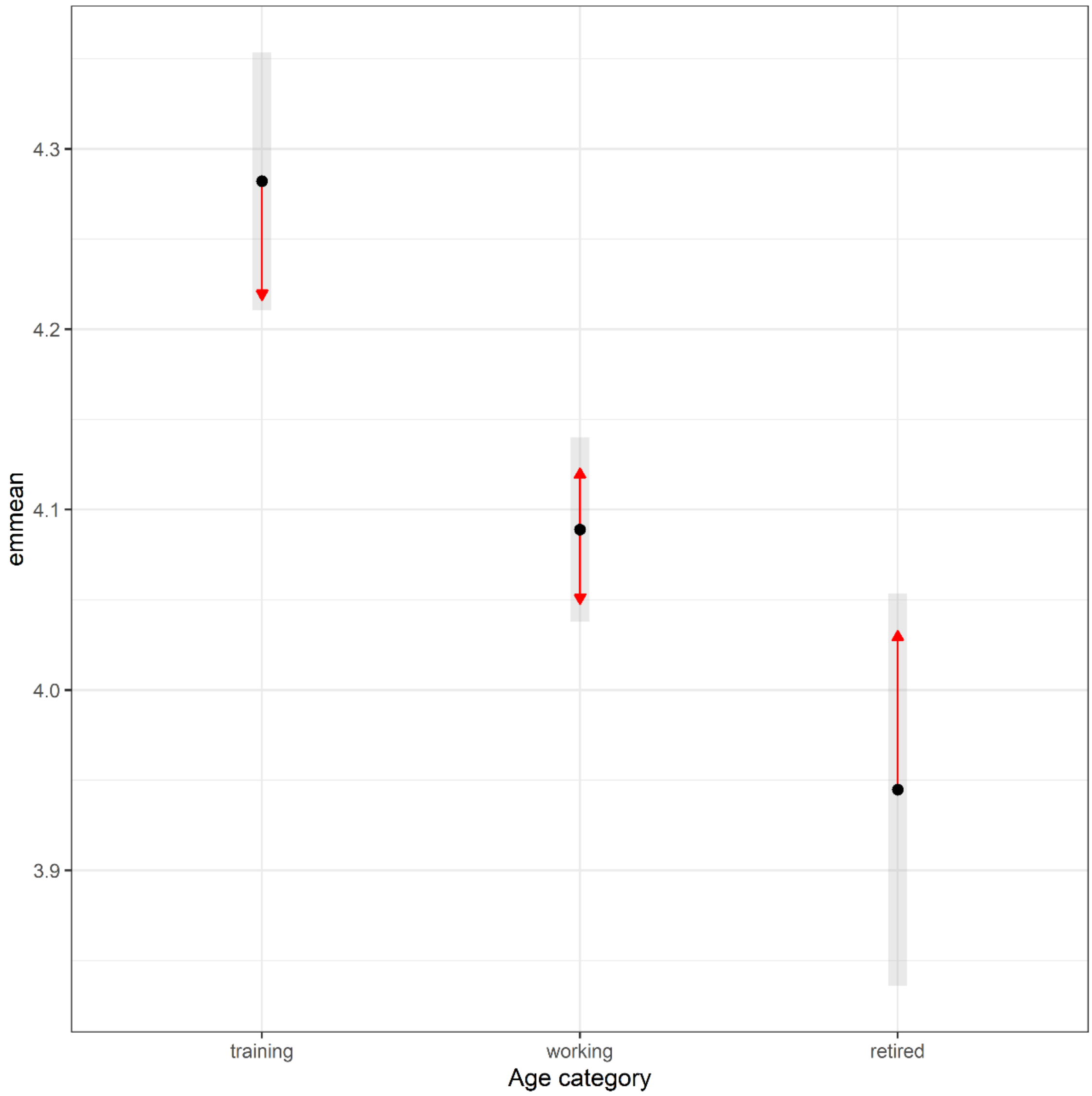

Fig 7. Post-hoc comparisons of estimated marginal means of FGM concentrations of the three age categories. When the red arrows overlap then there is no significant difference between the groups.

4 Discussion

In this thesis, I investigated whether elephants captured from the wild displayed higher stress levels in captivity, as measured by their faecal glucocorticoid concentrations, as compared to elephants living in the same logging camps in Myanmar but originally born in captivity. Age and season at sampling showed a significant relationship with FGM concentrations, with FGM concentrations highest in training elephants, followed by working elephants and with FGM concentrations being highest in the hot season. However, I did not find any significant link between the origin of the elephant (wild-caught or captive born) and FGM concentrations in multivariate models. When only investigating the link between origin and FGM concentrations in a univariate model, I did find evidence that wild-caught elephants had significantly lower FGM concentrations compared to captive born individuals. When including age and season into the model, the effect disappeared, suggesting that the difference in FGM concentrations between elephants of different origin is not very strong and not supportable by the data.

As the present study was planned out, the working hypothesis predicted wild captured elephants having lower body condition because of stress, higher stress hormone levels and higher infection levels from weakened immune systems induced by stress. These expectations were based on previous findings about differences in survival and reproduction of wild-caught and captive born elephants, and how stressful experiences capture, and taming are for them (*Lahdenperä et al. 2018; Lahdenperä et al. 2019*). In the end this hypothesis did not gain support, as the origin of the studied elephants was found to not affect their stress levels in a significant manner. Age and season were indeed found to be significant, yet origin was not, which proved surprising and led to speculation on the reasons behind these results.

Season in which the data was collected was also shown to be a significant factor in the stress levels of these elephants, with the hot, dry season from mid-February to mid-May proving the most stressful period for the elephants as measured by their faecal glucocorticoid concentrations. It is therefore not surprising that timber elephants are allowed to rest throughout the hottest months. The present study's results are in line with others that highlight the effects of heat on elephant cortisol levels (*Marcilla et al. 2012*) and the risks from heat stress that climate change could cause for Asian elephant populations in the future (*Li et al. 2019*). However, previous studies have sometimes found other seasons to have the highest FGM concentrations (*Seltmann et al. 2019*), such as when *Mumby et al. (2015)* found the monsoon season to be most significant to FGMs, potentially because of the start of work and difficult conditions in the forests in that season. Age proved a significant factor for FGM concentrations, with younger elephants going through their training years displaying the highest values despite their generally lighter workload, whereas adult working age elephants showed the widest range in their FGM concentrations. Perhaps the training age elephants are not yet used to more routine and heavier workloads. Retired elephants might have various age-related health issues, but not having to do much of any labour anymore, clearly lowering their FGM concentrations on average.

One reason for not finding support for the starting hypothesis is that nearly all wild-caught elephants in the study population have already had years to adjust into captivity, meaning that the higher mortality of wild-caught individuals could have resulted in the weakest elephants having already died before the data used in the present study had been collected, potentially skewing the results (known as "selective disappearance", *Lahdenperä et al. 2018*). Furthermore, the sampled elephants had had a long period to adjust to the semi-captive environment, potentially reducing their stress levels from those experienced earlier following the capture from the wild.

It should also be noted that the study population is called semi-captive for a reason; since the elephants have access to their natural habitat outside of working hours, allowing them to freely mingle with wild elephants, even the captive born elephants of this population live in much more wild-like conditions (sharing their sources of food and disease with each other) than the average captive zoo elephant (*Lahdenperä et al. 2018; Crawley et al. 2020; Seltmann et al. 2022*). This unusual setting provides the present study one of its biggest strengths, helping to level the gap of living conditions between zoo animals and their wild relatives, yet permitting the relative ease of data collection from captive animals. The close contact between semi-captive and wild elephants in the studied population might help explain why the origin of these elephants, captive born or not, did not show significant differences as hypothesised.

Potential future avenues for investigation might include other measured factors in the study population, such as body weight and the total white blood cell-levels. Adding to the results of the present study and previous research on, as an example, elephant white blood cells (*Dos Santos et al. 2020*), or the effect of seasons on elephant body weight (*Yang et al. 2023*) could help draw a more complete picture of elephant well-being and immune system function. It is fortunate this data exists, since the current volatile and unstable political situation within the country is complicating possible future studies on the timber elephants of Myanmar. Cooperation with locals and the acquisition of new data could prove difficult, and if conditions in Myanmar continue to deteriorate, the long-lived and meticulous records on the elephants and their life histories might even be disrupted.

What makes researching the topics covered in this thesis important is the knowledge gained regarding what factors affect the stress hormones of elephants and therefore their health, lifespan, quality of life, what could be done to detect stress-related problems easier and help prevent long-term stress in elephants and captive animals in general. Since long-term stress harmfully impacts the physical and mental well-being of animals (*Mason 2010; Jackson et al. 2019*), such as by decreasing their fertility rates (*Clubb et al. 2008)*, it also hampers efforts to breed endangered animals in captive conditions. It is therefore not only a question of more effective captive breeding efforts, but also an ethical imperative to make sure captive animal populations can live healthier and more fulfilling lives through careful management and enrichment, and that their living conditions are as suitable as possible for them. It is worth noting here that total absence of stress for captive animals is not a realistically attainable goal nor even good for their health, especially if they or their offspring are expected to be rewilded at some point (*Kleiman et al. 2010*). What matters is keeping the temporary, naturally occurring and situationally beneficial increases in stress hormone concentrations from becoming a long-term issue caused by avoidable poor living conditions. If captive populations of Asian elephants can be kept healthy and genetically viable, there will be less need for pressure on endangered wild populations through capture.

4.1 Final conclusions

The present study's results found that season and the age of Asian elephants in the Myanmar timber industry was linked to the levels of faecal glucocorticoid metabolites, whereas their origin, whether wild-caught or captive born, was not. This would imply that while the event of capture itself is extremely stressful (*Lahdenperä et al. 2019*), captured elephants eventually seem to adapt to their new life in timber camps, perhaps aided by their access to natural habitats, natural behaviours and natural interactions with wild conspecifics that is far superior to that available to most zoo elephants. Long-term differences and potential bad effects on physiology, mental health or behaviour were not found to be reflected by difference in FGM concentrations, though this alone does not rule their potential existence out. Further research using additional variables is recommended.

5 Acknowledgments

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