Behavioural thermoregulation of a chimpanzee population (*Pan troglodytes*) living in a high-elevation forest in Rwanda

Final Report

Hassan Al Razi

PhD Candidate, School of Human Sciences

The University of Western Australia

Contact/Email: hassan.alrazi@research.uwa.edu.au

Summary

Understanding behavioural thermoregulation in great apes is essential for interpreting their ecological flexibility and adaptive responses to climatic variability. We conducted a 12-month field study (March 2024–February 2025) on a high-elevation population of chimpanzees (Pan troglodytes) in Nyungwe National Park, Rwanda (up to 3000 m asl), to examine how individuals adjust behaviour and nest construction in a cool, humid montane environment. Behavioural follows were combined with detailed nesting ecology and microclimatic measurements, including overnight temperature, wind speed, humidity, and rainfall recorded at nesting sites. Nest morphology and tree characteristics were quantified, and nest insulation capacity was assessed using temperature loggers to estimate rates of heat loss. Nyungwe chimpanzees exhibited flexible thermoregulatory responses across behavioural and structural domains. During cooler conditions, individuals more frequently adopted curled resting postures and engaged in behaviours consistent with heat conservation. Nest site selection varied predictably with overnight weather: colder conditions were associated with nesting in shorter trees with reduced crown height, windy conditions with selection of larger trees with greater leaf area, and rainfall with denser canopy cover. Interactions among humidity, rainfall, and wind further influenced site choice. Nest architecture contributed to thermal buffering, as thicker and more structurally complex nests reduced heat loss. Together, these findings provide the first empirical evidence that montane chimpanzees adjust activity patterns, postural behaviour, nest site selection, and nest construction in response to fine-scale climatic variation. The results highlight the importance of behavioural flexibility in mediating thermal challenges at high elevation and contribute to a broader understanding of intraspecific variation in chimpanzee ecological adaptation under changing climatic conditions.

Introduction

Behavioural thermoregulation covers a variety of strategies i.e., microhabitat selection (Kearney et al., 2009; Terrien et al., 2011; Downs et al., 2013), basking and body positioning (Warnecke et al., 2010; Kelly et al., 2016), reduction of energetically costly activities (Grueter et al. 2013), changes in energy intake (Grueter et al., 2009; Westerterp-Plantenga, 1999), nest building (Terrien et al., 2011), and social thermoregulation, i.e., huddling and nest sharing (Gilbert et al., 2010; Li et al., 2010; Mitchell et al., 2018). Microhabitat selection or the searching out for cooler and warmer habitats ('spatial thermoregulation') and changes in activity budgets are universal thermoregulatory behaviours that mammals employ to alter their rate of heat loss or gain (Grueter et al., 2013; Campbell et al., 2018). More complex thermoregulatory behaviours, such as the construction of nests or burrows, are shown by a smaller range of species (Terrien, 2011).

Like other homeothermic animals, primates deal with a change in the environmental temperature using both physiological and behavioural mechanisms of thermoregulation. They need to maintain their optimal body temperatures despite being exposed to a thermally dynamic environment that changes daily, seasonally, and annually (Thompson et al., 2014). Therefore, there is likely to be a great deal of diversity in behavioural thermoregulation among primates. Compared with physiological thermoregulation, we know relatively little about behavioural thermoregulation in primates (Donati et al., 2011). Understanding the thermoregulatory behaviour of primates, in particular the great apes, is important because of their close phylogenetic relatedness to humans. As chimpanzees and humans share a common ancestor, we can obtain valuable information on the likely behavioural evolution of early hominins by studying the thermoregulatory behaviour of chimpanzees. For example, chimpanzees build nests or sleeping platforms, and the earliest hominins presumably used shelters at night, so we may gain important insights into the behaviour of early hominins by studying the ecological aspects of nest-building in chimpanzees (Stanford, 2018).

Primates exhibit both spatial thermoregulation and nest building to maintain an optimal body temperature (Terrien et al., 2011). Moreover, primates can alter their body posture in a way that aids with heat balance, e.g., by hunching in cold weather and spreading their limbs in heat (Stelzner & Hausfater, 1988). Almost all species of primates show spatial thermoregulatory behaviour, but nesting behaviour has been observed only in the great apes. Great apes prepare nests for day and night sleeping and the purpose of nest building is multifunctional. Several hypotheses have been proposed to explain nest building in great apes, viz. antipathogen, antipredation, sleeping comfort, and thermoregulation (Stewart, 2011). These have been most thoroughly studied in chimpanzees (*Pan troglodytes*). Research has shown that the construction of night nests can be explained by its thermoregulatory benefits.

Chimpanzees have a wider geographic distribution range than any other great ape and inhabit a variety of habitat types from dry savanna to moist montane forest (Williamson et al., 2013). All past studies of chimpanzee nesting were done exclusively on populations in low to mid-elevation forests (Baldwin et al., 1981; Stewart, 2011; Stewart et al., 2018; Koops et al., 2012). The possible thermoregulatory function of great ape nests in cool montane environments has received no empirical consideration to date. Here we focus on a chimpanzee population in Nyungwe Forest National Park, where chimpanzees range up to 3000 m asl, which is the upper limit of their elevation range (Williamson et al., 2013). Previous work by Cyril C. Grueter and his doctoral students has focused on grouping patterns, route use, activity and ranging patterns, and feeding ecology of the Nyungwe chimpanzees, with the aim of documenting adaptations to this high-elevation environment (Grueter et al., 2022; Green at al., 2020a, 2020b; Matthews et al., 2019). In this study, we examined the behavioural thermoregulation of these high-altitude chimpanzees in Rwanda and address the following objectives:

1. Enhance Understanding of Species-Specific Adaptations

The main objective of this study is to increase our understanding of how montane chimpanzees adapt their behaviour to cope with temperature fluctuations in their high-altitude habitat. By documenting the specific strategies these chimpanzees employ, such as changes in activity budgets, basking behaviour, ground use, and postural adjustments, we can gain insight into their unique adaptive mechanisms. This knowledge is crucial for species conservation, as it helps to identify critical behaviours and habitats that support the survival of chimpanzees in such challenging environments. Understanding these adaptations may also inform conservation strategies in regions with similar environmental pressures.

2. Inform Habitat Management and Protection

The findings from this research could guide habitat management practices within Nyungwe National Park. For instance, if the study reveals that chimpanzees prefer nesting sites with specific microclimatic conditions, such as lower wind speeds or higher temperatures, conservation efforts can prioritise the protection of these critical areas. By ensuring the availability and preservation of suitable nesting sites, conservationists can support the chimpanzees' ability to thrive in their natural habitat. Additionally, understanding the influence of ambient temperature on nesting site selection may help predict how climate change could impact the availability of suitable nesting sites in the future.

3. Comparison with Other Chimpanzee Populations

By comparing the behavioural thermoregulation strategies of Nyungwe's montane chimpanzees with those of savanna chimpanzees in hotter environments, this study will contribute to a broader understanding of intraspecific variation in chimpanzee behaviour across different habitats. This comparison can shed light on the flexibility and limits of chimpanzee behavioural adaptations, providing essential data for species-wide conservation strategies. Such information can be used to prioritise areas for conservation that support the species' ability to adapt to diverse environmental conditions.

Field Activity

We conducted a 12-month fieldwork project from March 2024 to February 2025. Each month, our fieldwork is divided into two phases. In the first phase, primarily during the second week of the month, we collect data on the activity budget of the chimpanzees. We follow the chimpanzees from the morning to evening until they make their nests. During this time, we collect their different behavioural activities in relation to different environmental variables (temperature, humidity, wind speed, etc.). The second phase is dedicated to nesting data collection. We start by setting up a mini weather station close to the nesting site to capture local environmental conditions. On the following day, we record detailed data on nest morphology, the characteristics of the nesting tree, and the microhabitat around the nest. We assess nest insulation properties by placing a hot water bottle equipped with a temperature logger in the nest, allowing us to evaluate the thermal qualities of the nests without dismantling or removing any material. As chimpanzees of Nyungwe National Park reuse their nests, we didn’t take any nests to the ground or destroy any nests. We collect all the data by climbing the tree and try our best to minimise the manipulation of the nests.

Key Observations and Findings:

1. Weather of Nyungwe National Park

The weather in Nyungwe National Park is characterised by a cool and humid montane tropical climate with distinct seasonal variations. During our study, we found the average monthly temperatures remain relatively stable throughout the year, ranging between 14°C and 17°C, with slightly cooler conditions during June and July. Humidity is consistently high, peaking around 85–90% during the wet months of March, April, and November, and dropping to approximately 65% during the drier months of August and September. Wind speeds are generally low but increase modestly during the dry season (June to September), particularly in July and August. Rainfall patterns follow a bimodal distribution, with pronounced rainy seasons in March–April and October–November, and a clear dry period from June to August. March receives the highest rainfall (386.6 mm), while June and July are the driest months, receiving only 3.6 mm and 12.5 mm of rainfall, respectively (**Fig. 1**). These climatic conditions significantly influence ecological processes and species behaviour within the park.

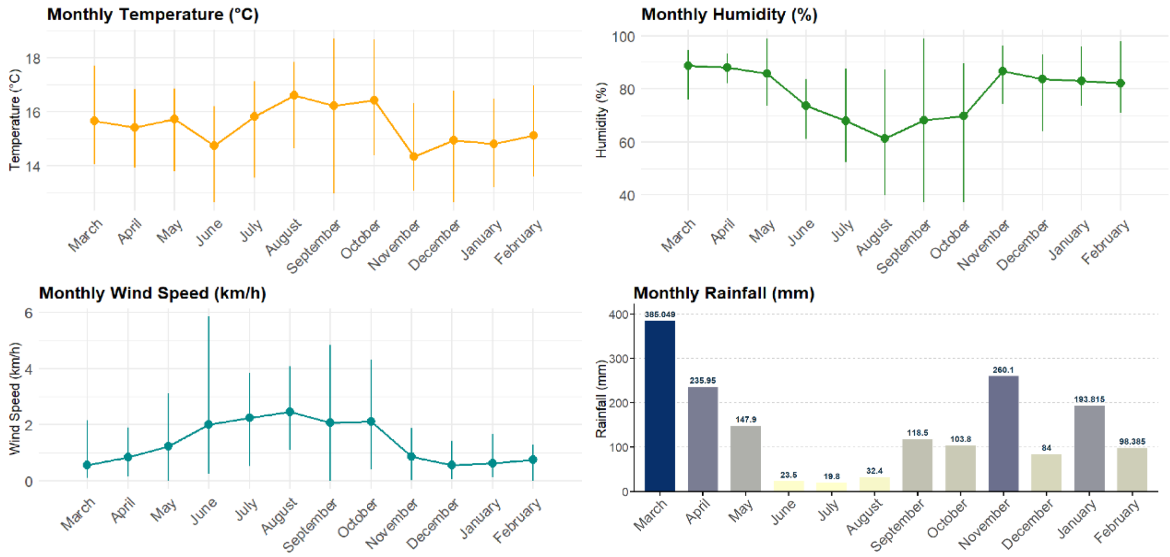

Figure 1: Weather conditions in Nyungwe National Park during the study.

2. Behavioural Thermoregulation

Preliminary data suggest that chimpanzees in the Mayebe community engage in specific behaviours to regulate their body temperature, such as resting in shaded areas during peak heat and huddling during cooler periods. This behaviour was particularly noted at higher altitudes where temperature fluctuations are more pronounced. Resting postures like the curled position were more frequently observed during cooler periods, likely as a strategy to conserve heat (**Fig. 2**).

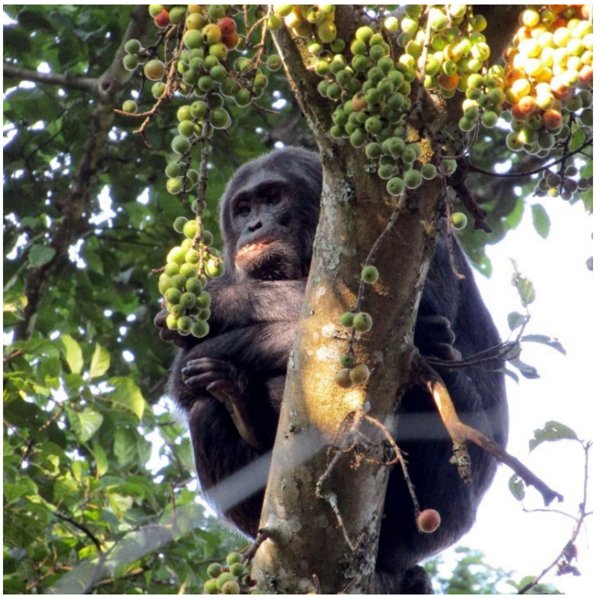

Figure 2. A male chimpanzee is eating food with a curled posture.

3. Nesting Site and Nesting Tree Selection

Chimpanzees preferred nesting sites with specific microclimatic conditions, such as lower wind speeds and higher canopy cover, which likely offer better thermal insulation and protection from the rain. Nesting sites were generally at elevations that provided optimal thermal conditions. Using a mini weather station, we recorded overnight temperature, wind speed, humidity, and rainfall at nesting sites. The following day, we measured tree characteristics, including DBH, tree height, crown height, distance of nesting branch from the main trunk, and leaf area. Overnight temperature significantly influenced tree selection. On colder nights, chimpanzees nested in shorter trees with shorter crowns, while in warmer conditions, they selected branches farther from the main trunk with less canopy cover. Wind speed was positively associated with the selection of trees with larger DBH and higher leaf area, indicating a preference for bigger trees and larger leaves in windy conditions. On rainy nights, chimpanzees built nests under denser canopy cover. While humidity alone had no significant effect, its interaction with rainfall and wind speed played a key role in nest site selection.

4. Nest Morphology and Insulation:

Fresh nests were observed to have intricate morphology that varied based on the nesting plant species. The thickness and complexity of the nest structure were found to be critical for thermal insulation. Initial tests of fresh, natural nests showed that the rate of heat loss was significantly lower in well-constructed nests, confirming the role of nest architecture in maintaining thermal comfort. The final data analysis will show the insulation of the nests based on different weather conditions.

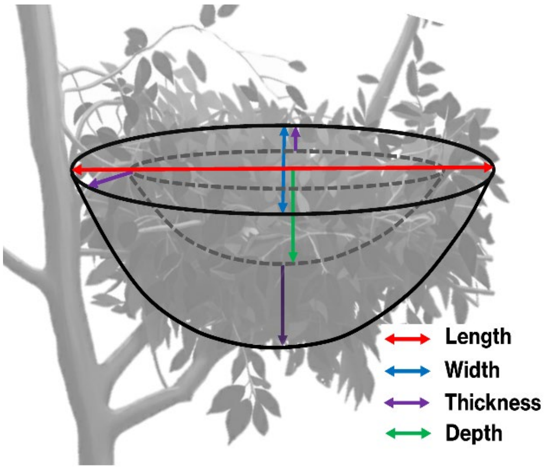

Figure 3. Nest structural measurements. Schematic showing the four dimensions measured: length (maximum horizontal diameter), width (perpendicular horizontal diameter), depth (rim to lowest inner point), and thickness (outer base to lowest inner point).

Challenges in the field

1. **Environmental and Logistical Challenges:**

Variable Weather Conditions: The unpredictable and often harsh weather conditions in Nyungwe National Park, including heavy rains and cold temperatures, have occasionally disrupted data collection. This led to a few gaps in the observational data, particularly during extreme weather events when it was challenging to monitor chimpanzee behaviour accurately. Due to heavy rain, we sometimes lost chimpanzees and couldn't take behavioural data continuously.

Terrain Accessibility: The rugged and densely forested terrain of Nyungwe posed significant challenges for consistent observation. Certain areas where chimpanzees are known to nest were difficult to access. Besides this, sometimes we couldn't follow the chimpanzees till nesting.

2. **Behavioural Variability**

Chimpanzee Habituation: Although the chimpanzees in Nyungwe are habituated, their behaviour still varies significantly. Sometimes, they moved very fast, and it was difficult to follow them. This made it challenging to gather consistent data on certain behavioural strategies, such as postural changes and ground use.

3. **Data Gaps**

Nest Architecture: At the beginning of the study, we collected some data on nest architecture under different overnight weather conditions. We took the nests on the ground to collect the data. After a few days, we found that the chimpanzees of Nyungwe National Park reuse their nests, and we decided not to manipulate the nests. Then we just took the nest shape, size and insulation data.

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Some photos from the field