Cloudbridge Nature Reserve Research Project

Asocial and social behaviour of White-nosed Coati *(Nasua narica)* at high and low altitude within the Talamanca Mountains, Costa Rica

Abstract

White-nosed Coatis *(Nasua narica)* maintain a complex social structure that involves both sociality (groups/bands) and asociality (solitary individuals) behaviour. This social structure can be impacted by many environmental influences within their habitat. This study will examine the differences in behaviour and distribution of White-nosed Coati at high and low altitude within Cloudbridge Nature Reserve. Coati behaviour was recorded over a three-month period using camera traps and was coded using event logging software Boris. 314 coatis were observed on camera trap footage over the length of the study. Behaviours such as foraging, digging, tail motion and locomotion were most commonly recorded. Using time budget data, a series of two sample T-tests assuming unequal variance, found that altitude had no impact on distribution (*p-value range = 0.2- 0.54*), but influenced behaviour (*p-value range = 0.001-0.03 range*). Higher percentage of asocial behaviours was observed at high altitude, whilst a higher percentage of social behaviours at low altitude. Concluding findings illustrate the importance of understanding if altitude influences sociality and asociality in the White-nosed Coati, for conserving species populations.

Keywords: Altitude ◦ Asociality ◦ Camera Trap ◦ Distribution ◦ Social Grouping ◦ Species Behaviour

Introduction

Defining Social and Asocial Behaviour

Asocial behaviour in its simplest form is the avoidance of social interactions with other individuals of the same species (LaLand, 2004), while social behaviour is interactions that occur between individuals (Seebacher, 2017). Social grouping is a common living practice exhibited in the animal kingdom, with many animals adopting it as a way of achieving a favourable outcome or increased survival rate (Gompper, 1996; Reader, 2016). However, some species exhibit both social grouping and asociality, for example male cheetahs can form coalitions with other males for defending territories and attracting females, while females predominately are solitary due to the cost of sharing prey (Gompper, 1996). Moreover, solitary behaviour has been documented in male mantled howler monkeys *(Alouatta palliata)* in the Costa Rican rainforest, who live part of their lives segregated from social living groups of females and juveniles (Bolt, 2020). Solitary behaviour can be beneficial, with less attention and attraction from predators that would be more prevalent living in a larger group (Bolt, 2020).

Role of Altitude

Animal behaviour can be influenced and shaped by both internal and external stimuli. Both asocial and social behaviour can be linked to interactions with the environment. External stimuli such as altitude has the potential to alter behaviour. Solitary individuals, within species that possess diverse habitat ranges, can potentially venture to higher altitudes due to a lack of dependency on juveniles and inconsiderable risk posed by predators at higher altitude (Gompper, 1996). Higher altitudes have potential to provide affluent food sources, which solitary individuals can avail off (Frehner, 2018). Small herbivorous mammals like the yellow-rumped leaf-eared mouse (*Phyllotis xanthopygus)* whose habitats are in mountainous landscapes, have high variation in their diet linked with diversity in altitude (Sassi et al, 2017).

Measuring Behaviour

Assessing an animals behaviour and population level within its habitat, can rarely be acquired using simple methods alone (Burton et al, 2010). Direct observation of animal behaviour is limited, with human presence more than often impacting how an animal behaves (e.g., avoiding or running from humans), therefore alternatives such as camera traps are universally used to study behaviour (McCarthy et al, 2018). Camera trapping is a growing trend utilised in a range of animals studies trying to understand species distribution, population estimates and behaviour. Unlike lab-based behavioural research, camera trapping raises no ethical or logistical concerns, and does not remove an animal from its natural habitat (McCarthy et al, 2018). This makes the method valuable in the fight to resolve the global biodiversity crisis, as animals are free to express normal behaviour without human interference (Butchart et al, 2010).

Species Management

Conservation is associated with animal research, as wildlife biologists now have an obligation towards helping to minimise the impacts of climate change by attempting to solve the global biodiversity crisis (Singh, 2002). Procuring knowledge of what species inhabits a particular environment is crucial for designing of new conservation projects, and sequentially aiding population growth. Projects associated with the landscape can be instrumental for species management, by gaining knowledge of the geological area and providing buffer zones for protection around environmentally diverse habitats (Murphy, 2004). However, buffer zones can only be effective with an apprehension of the movement patterns and behaviour of species enclosed. Implementing behavioural research can allow us to understand how an animal behaves in response to changes in its environment, and therefore aid in implementation of conservation projects (Caravaggi et al, 2017). With limits on governmental funding for conservation, there is an importance in predicting how animal populations will be impacted by continual changes in their habitat (Smith, 2005; Sutherland, 1998).

Study Parameters

This study aims to understand how the behaviour and distribution of White-nosed Coati can alter at contrasting altitudes. The project will centralise on observing the behaviour of solitary individual's (asocial behaviour) and group living bands (social behaviour). From distribution data, the study lends itself to a null hypothesis (H_0) that altitude influences distribution, due to perceived notion that coatis are widely distributed and follow no structured movement pattern (Romp, 2019). From behavioural data a second null hypothesis (H_0) that altitude has no effect on the occurrence and duration of social and asocial behaviour. Fielding the theory that the data observed is a result of chance. An alternative hypothesis (H_a) may arise if the null can be disproved in both cases, with observed data the result of definitive causes. Furthermore, distribution and behaviour are predicted to alter due to factors that are simultaneous with altitudinal change, including predation, climate, and food availability. Discussions on the usefulness of camera traps as a method for interpretating species behaviour is imperative to our understanding of species interactions with the environment (Butchart et al, 2010).

Methodical design

Study Area

This study explores differences in asocial and social behaviour of White-nosed Coati at contrasting altitudes within Cloudbridge Nature Reserve, located in the Talamanca Mountain range (Figure 1). Residing on an elevational gradient of 1500-2200m above sea level, the reserve provides a perfect opportunity to explore effects of contrasting altitudes on species distribution and behaviour. Cloudbridge is classified as a tropical cloud forest, with moisture obtained from both rainfall and cloud cover. Costa Rica has defined wet (May-November) and dry (December-April) seasons, with

Cloudbridge experiencing an average annual rainfall of 6.6mm, and an average temperature of 18°C (Romp, 2019). The reserve is home to a fragile cloud forest ecosystem, sheltering a diverse, but rare range of fauna (Romp, 2019). Species such as Black-handed Spider Monkey *(Ateles geoffroyi)* and Baird's Tapir *(Tapirus bairdii)* can be found at Cloudbridge, which are listed as endangered on the IUCN Red list (Asensio, 2012; Castellanos et al, 2015). Rare species like this are poorly understood in terms of their population densities and behavioural traits, so selecting precise methods of measurement is key (Romp, 2019).

Figure 1 – Cloudbridge Nature Reserve, Costa Rica, Central America.

Study Species

White-nosed Coatis *(Nasua narica)* are small mammals (55 cm length, 4-6kg weight), that are part of the family Procyonidae (raccoons, kinkajous, olingos). Coati's wide dispersal range, from coastal areas to mountainous rainforests, makes them an adaptable species to contrasting altitudes (Henderson, 2002). White-nosed Coati social arrangement is intriguing, with females and young living together in varied band sizes (6-30 individuals), while adult males are generally solitary, except for a two-week breeding period (Gompper, 1996). This social arrangement is known to alter behavioural dynamics, for example individuals living in large bands are more likely to avoid predation compared to solitary males (Gompper, 1996; Hass, 2002). Conversely the benefits of group living are what makes coatis highly sociable mammals that are known for utilising problem-solving behaviour when foraging (Roubert-Olive, 2018). Cooperative behaviours observed in coati bands whilst foraging makes them the only species from the Procyonidae family to express social behaviour (Gompper, 1996).

Sampling Design

Data sampling revolved around the implementation of two Ceymour CY70 camera traps in the field (Figure 2). Camera traps were set to video mode, with recordings at a 30 second length, with a 10 second interval period between each recording. Camera traps were 24 hours operational in the field. Both camera traps were equipped with 32GB SD cards (2 in total) for data storage.

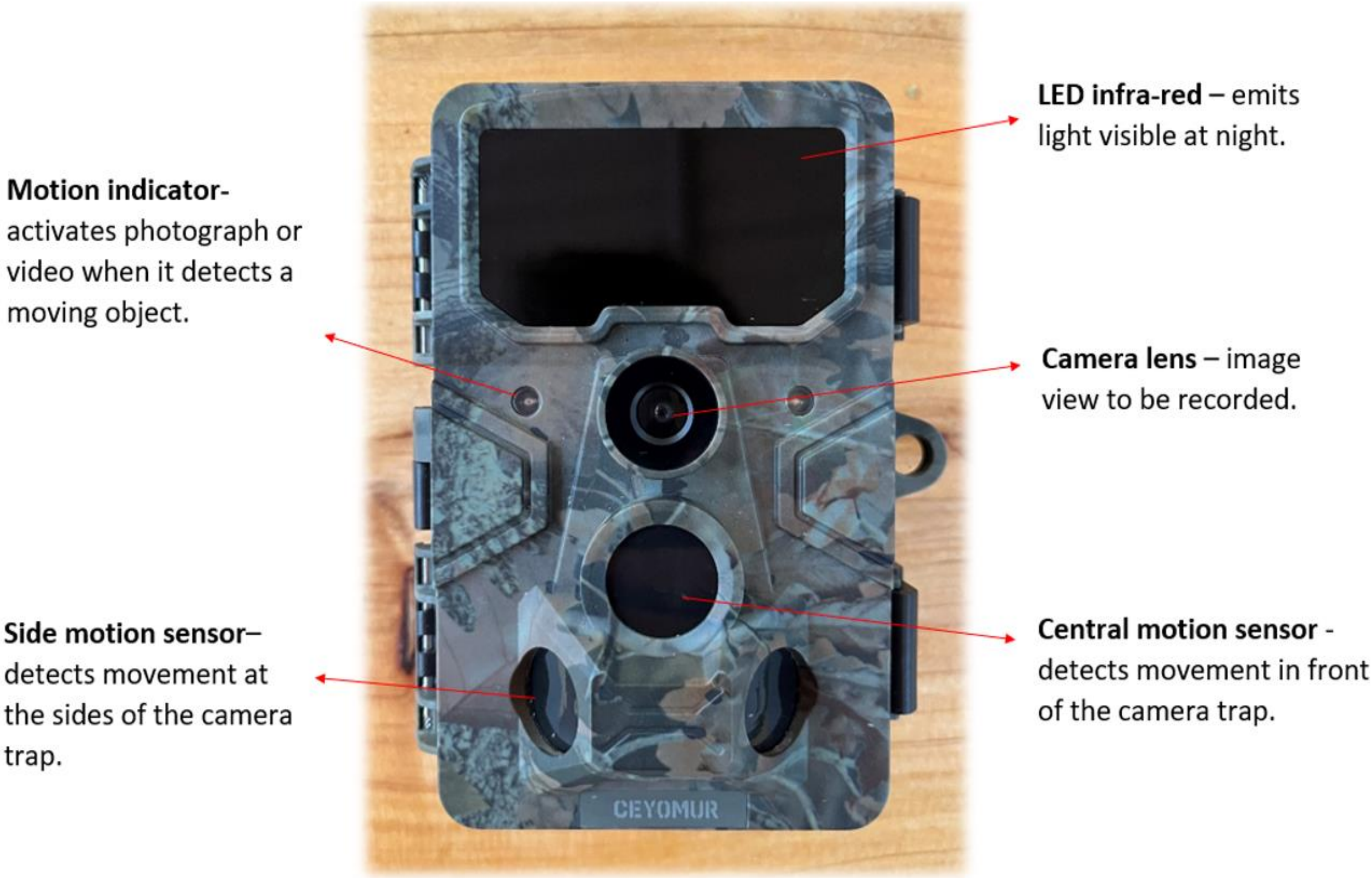

Figure 2 – Image of Ceymour CY70 camera trap used during fieldwork. Descriptions of each of the primary components of the camera trap illustrated above.

Data was collected over a period between May 2022- July 2022 during Costa Rican wet season. Pre-site surveys were conducted to understand the landscape at Cloudbridge nature reserve and to assess appropriate areas for observing White-nosed Coati. Camera trap data from January 2022-April 2022, stored on the Cloudbridge database, was utilised to see which trail had a higher recorded abundance of coatis. Moreover, locations for fieldwork were chosen based on study aims, altitude (1 high and 1 low location) and accessibility from the reserve trails. Culminating in four trails within the reserve chosen to conduct fieldwork (Figure 3). El Jilguero and Rio trails designated as first base points for fieldwork (first 3 weeks), with Gavilan and Principal, as second base points (7 weeks) (Figure 3).

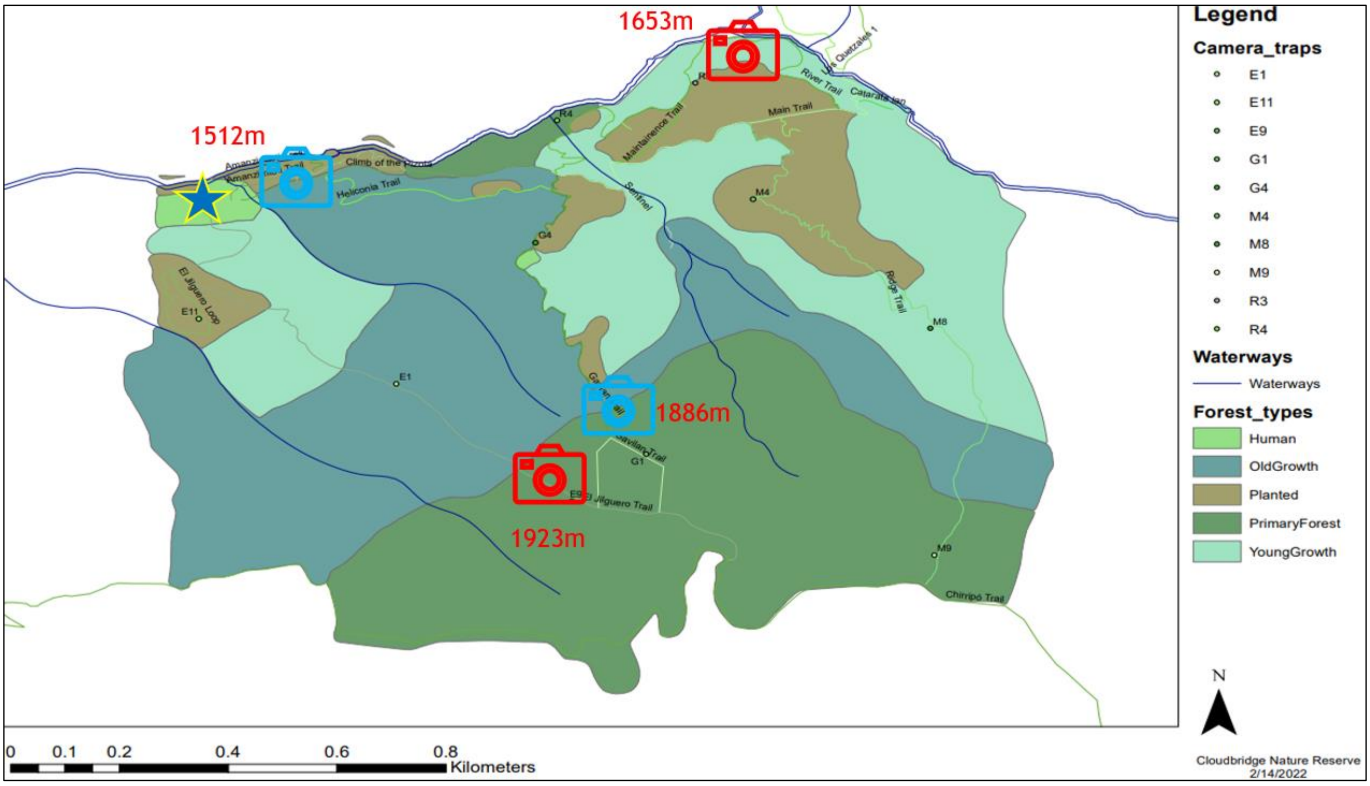

Figure 3 – Detailed map of Cloudbridge Nature Reserve, comprising forest types, waterways, trails, and current trail camera traps. Camera trap locations for fieldwork included (first camera trap locations in red, second locations in blue), along with altitude readings at each location.

Camera traps were left up longer at Gavilan and Principal, as they provided more suitable locations to observe coati activity. Altitude was determined using My Altitude GPS app, which provides an accurate altitude reeding to your mobile device (Cross et al, 2020). Data in the field was not collected over the first two weeks of May and last week of July, as these weeks were reserved for pre-site surveys and data analysis. Camera trap servicing (battery replacement) and SD card removal was performed every two weeks the camera traps were operational in the field.

Data Analysis

Distribution data was collated every two weeks after collection of SD cards. Comparisons across distribution was conducted from the number of recorded individuals observed on camera trap footage at high and low altitude. Due to the difficulty in individually identifying each coati captured on camera trap footage, distribution data was recorded based of occurrence. Each occurrence of a coati was categorised into a subgroup (adult, juvenile, solitary, group) in Microsoft Excel, and for statistical testing in R studio distribution data was broken down into three sub-classes (1. Solitary coatis, 2. Coati groups, 3. Individual coati distribution). Variance testing showed unequal variance across all high altitude and low altitude samples within the three sub-classes. Therefore, two sample

T-tests with unequal variances were performed to determine statistical significance between high and low altitude samples (Table 3).

Behavioural data (video footage) was examined after removal of camera traps from the field. For behavioural analysis Ad libitum sampling was employed as a method, which involves identifying as much behaviour as possible, with no focal subject. Camera trap videos were analysed and coded using Behavioural Observation Research Interactive Software (Boris) (Friard, 2016).

Four ethograms developed in Boris; 1. *Low Altitude (Social Behaviour) 2. High Altitude (Social Behaviour) 3. Low Altitude (Asocial Behaviour), 4. High Altitude (Asocial Behaviour).* Social behaviour examined from coati bands and asocial behaviour from solitary coatis.

Each ethogram was developed based of pre-defined behaviours from human observation (Table 1). Ethogram subjects were defined as adult and juvenile with no focal individual. Within Boris, observations coded were analysed as a time budget, indicating the amount and duration behaviours were performed. Time budget data was collated in Excel before performing two sample T-tests with unequal variances in R studio. Two sample Tests used to establish a significance in occurrence and duration of behaviours performed across differing altitude samples.

Table 1 – Example of pre-determined behaviours deduced from human observation of camera trap footage.

Behaviour code	**Description**
Walking	Normal movement using legs from one position to another
Standing	Stationary on back legs
Foraging	Actively searching for food
Sniffing	Using nose to search through environment
Sitting	Positioned in upright stance while not moving
Exploration	Looking around environment
Resting	Non-movement lying down
Digging	Using claws to dig into ground
Eating	Consuming food
Chirping	Displaying chirp noise
Biting	Using teeth to grip and tear an object
Scratching	Running paws through fur
Alertness	Head positioned upright, looking around
Tail motion	Tail positioned upright
Running	Faster movement than normal
Head shaking	Head moving from side to side
Shaking	Body moving from side to side
Climbing	Movement up a tree
Crawling	Movement flat to the ground

Results

Distribution

Table 2 – Number of recorded individuals observed on camera footage at contrasting altitudes across the three months of fieldwork. Table is split in two, with sub classes (Adult, Juvenile, Solitary, Group).

White-nosed Coati Distribution							
Month	***Category***	***High Altitude***	***Low Altitude***	***Month***	***Category***	***High Altitude***	***Low Altitude***
May-22	*Adult*	*43*	*14*	*May-22*	*Solitary*	*37*	*4*
May-22	*Juvenile*	*2*	*5*	*May-22*	*Group*	*3*	*5*
Jun-22	*Adult*	*61*	*82*	*Jun-22*	*Solitary*	*28*	*4*
Jun-22	*Juvenile*	*2*	*23*	*Jun-22*	*Group*	*10*	*15*
Jul-22	*Adult*	*20*	*46*	*Jul-22*	*Solitary*	*3*	*3*
Jul-22	*Juvenile*	*1*	*15*	*Jul-22*	*Group*	*5*	*11*

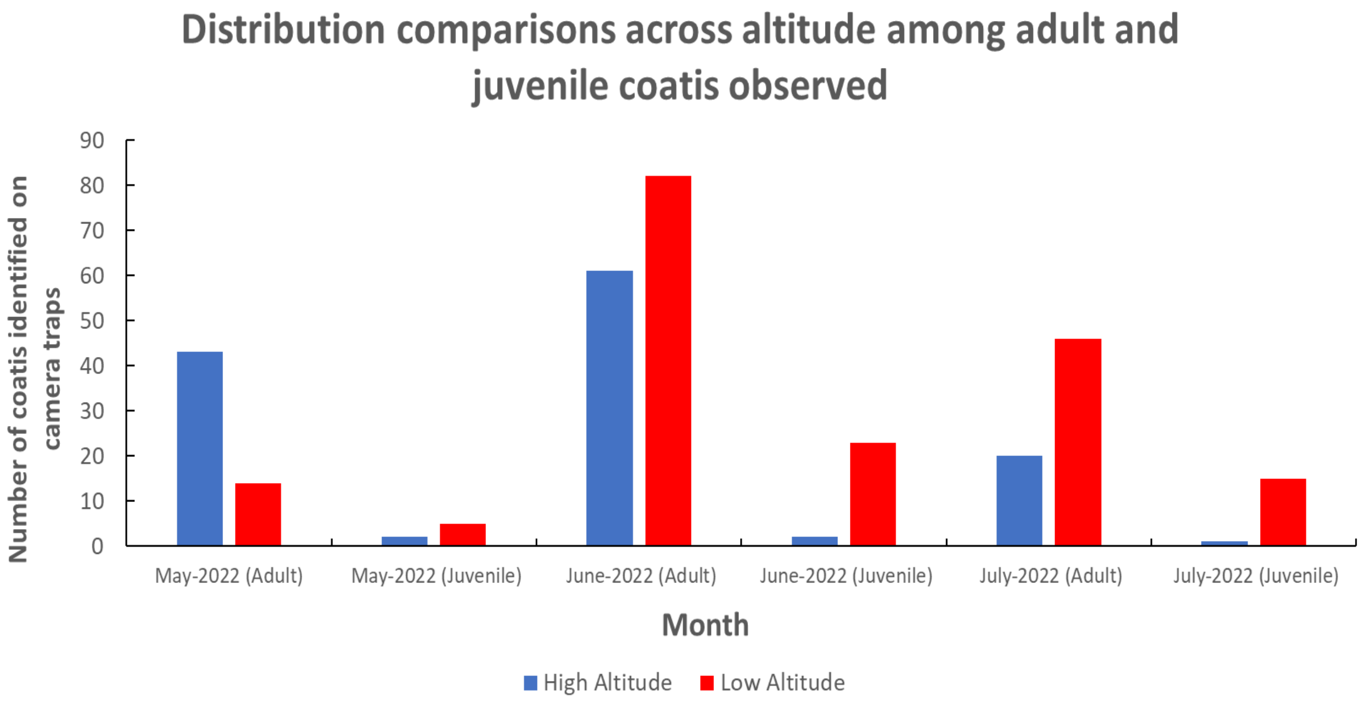

Figure 3 – Comparisons across altitude (high and low) between adult and juvenile coatis identified on camera traps over three months of operation in the field.

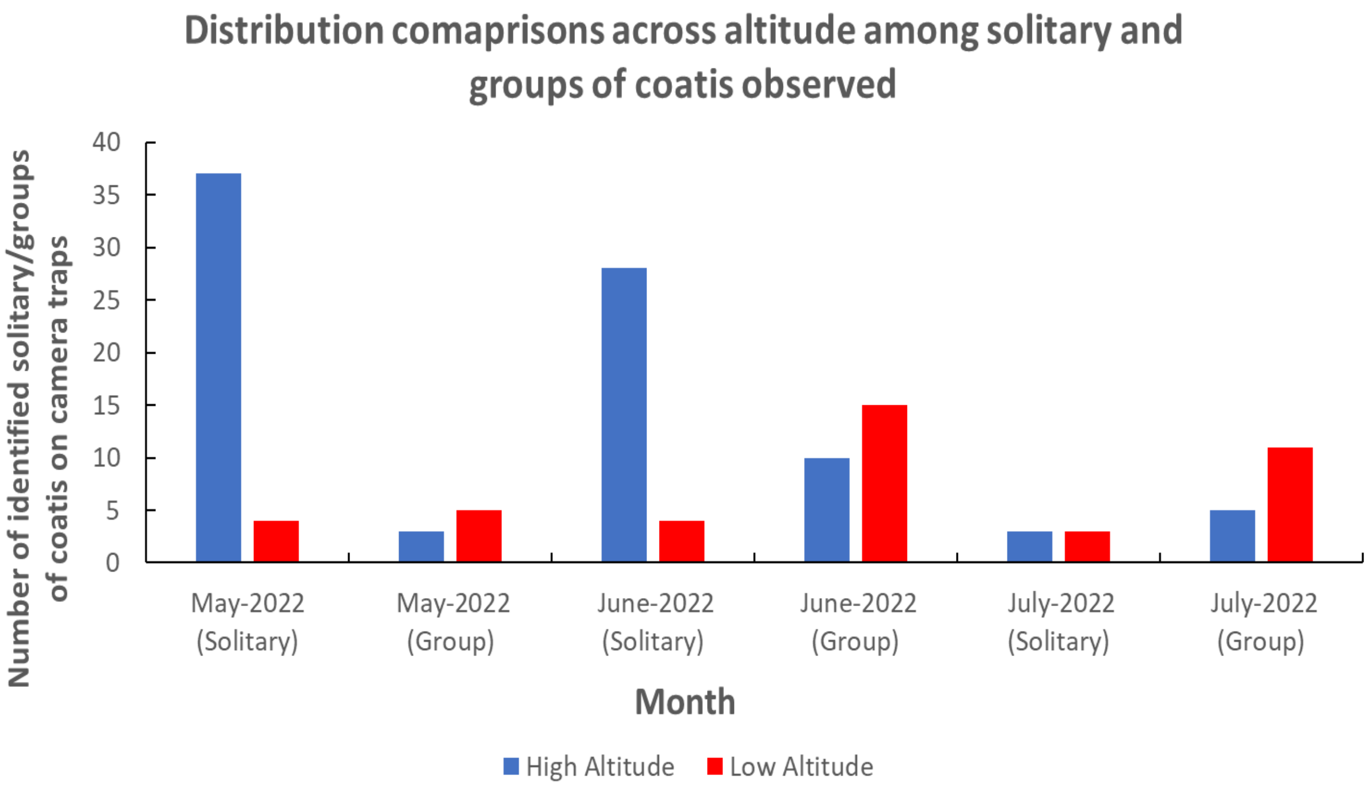

Figure 4 - Comparisons across altitude (high and low) between solitary and groups of coatis identified on camera traps over three months of operation in the field.

Table 3 – Two-sample T-test assuming unequal variances performed for three tests relating to distribution data obtained. Each of the three tests compared two samples of distribution, high altitude, and low altitude sample.

t-Test: Two-Sample Assuming Unequal Variances	
	P-value
Test 1 - Solitary Coatis	*P(T<=t) two-tail = 0.20*
Test 2 – Coati Groups	*P(T<=t) two-tail = 0.29*
Test 3 – Individual coati distribution	*P(T<=t) two-tail = 0.54*

All three tests p values exceeded the 0.05 significance level, therefore allowing for the null hypothesis to be rejected and concluding that altitude has no effect on coati distribution. Individual coati distribution test examined all coatis observed on camera trap footage. Sub-classes of adult and juvenile (Table 2) was not considered in the statistical testing.

Time Budget Analysis

Time budget analysis data was broken down into two parts for statistical testing, number of occurrences of behaviour and duration (timed length) of behaviours. 22 different social and asocial behaviours were identified across high and low altitude. Chirping was the only point event behaviour found. Most behaviours were identified across all four ethogram categories, except climbing, crawling, and standing behaviour, which were only identified at high altitude.

Number of occurrences of behaviour

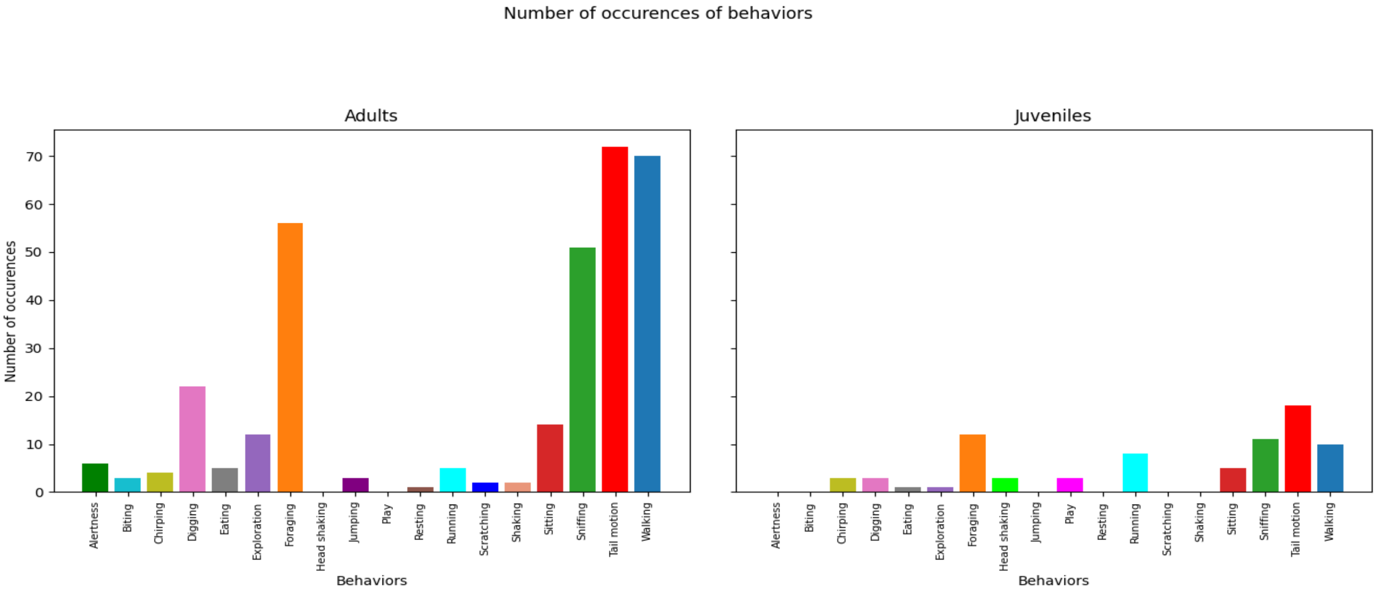

Figure 5 – Low Altitude (Social Behaviour): - number of occurrences of behaviours observed in group living adults (left side) and juveniles (right side) at low altitude. Each colour represents a different behaviour observed.

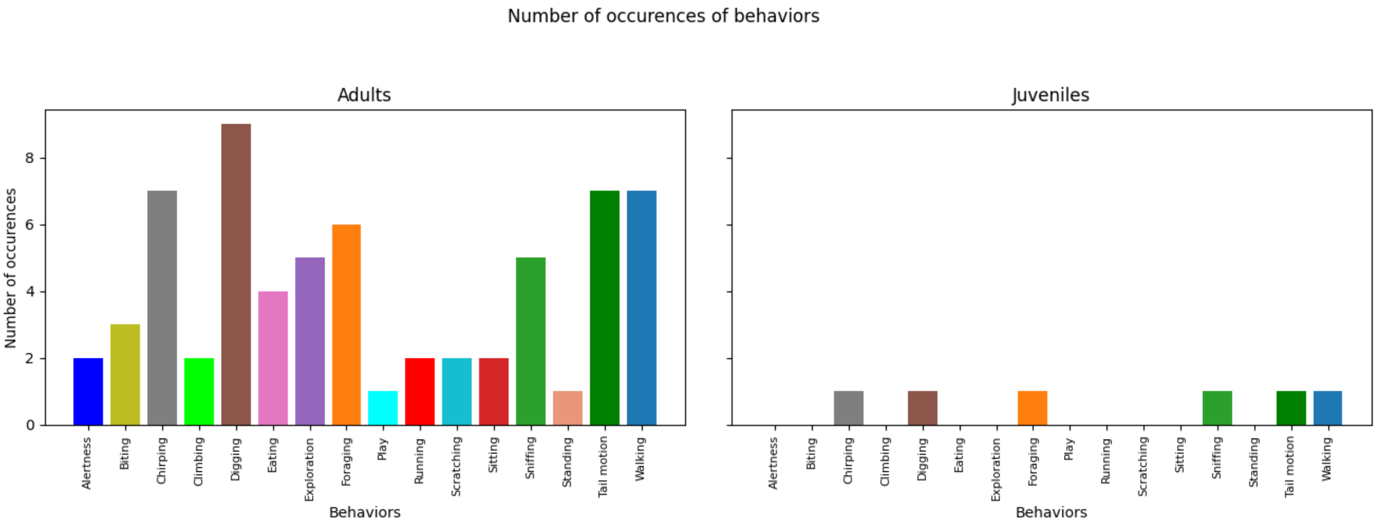

Figure 6 – High Altitude (Social Behaviour): - number of occurrences of behaviours observed in group living adults (left side) and juveniles (right side) at high altitude.

406 occurrences of social behaviour were observed at low altitude, whilst 71 occurrences of social behaviour were observed at high altitude. At low altitude walking behaviour was performed most with 80 occurrences across adults and juveniles. At high altitude digging behaviour was performed most with 10 occurrences across adults and juveniles. This is aside from tail motion which was a continuous behaviour performed.

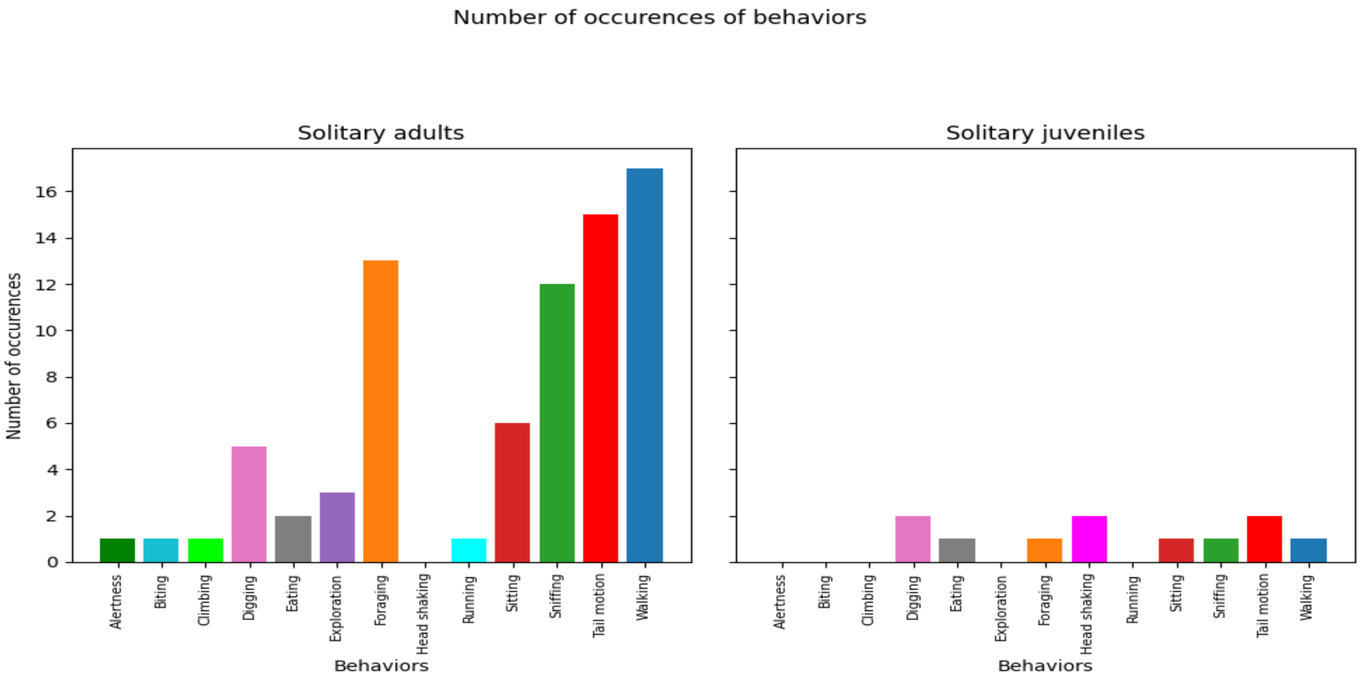

Figure 7 – Low Altitude (Asocial Behaviour): - number of occurrences of behaviours observed in solitary adults (left side) and juveniles (right side) at low altitude.

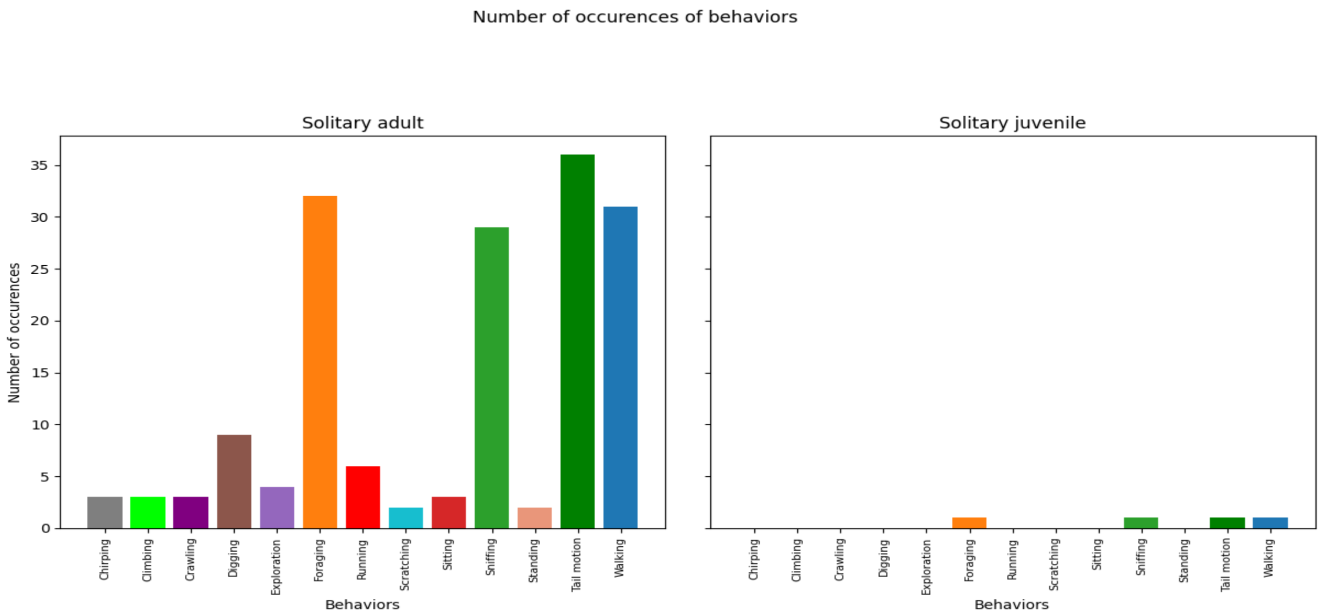

Figure 8 – High Altitude (Asocial Behaviour): - number of occurrences of behaviours observed in solitary adults (left side) and juveniles (right side) at high altitude.

88 occurrences of asocial behaviour were observed at low altitude, whilst 167 occurrences of asocial behaviour were observed at high altitude. At low altitude walking behaviour was performed most with 18 occurrences across adults and juveniles. At high altitude walking behaviour was performed most with 17 occurrences across adults and juveniles. Within asocial foraging behaviour at high altitude, two occurrences of tree foraging, a modified behaviour was observed.

Duration of behaviours

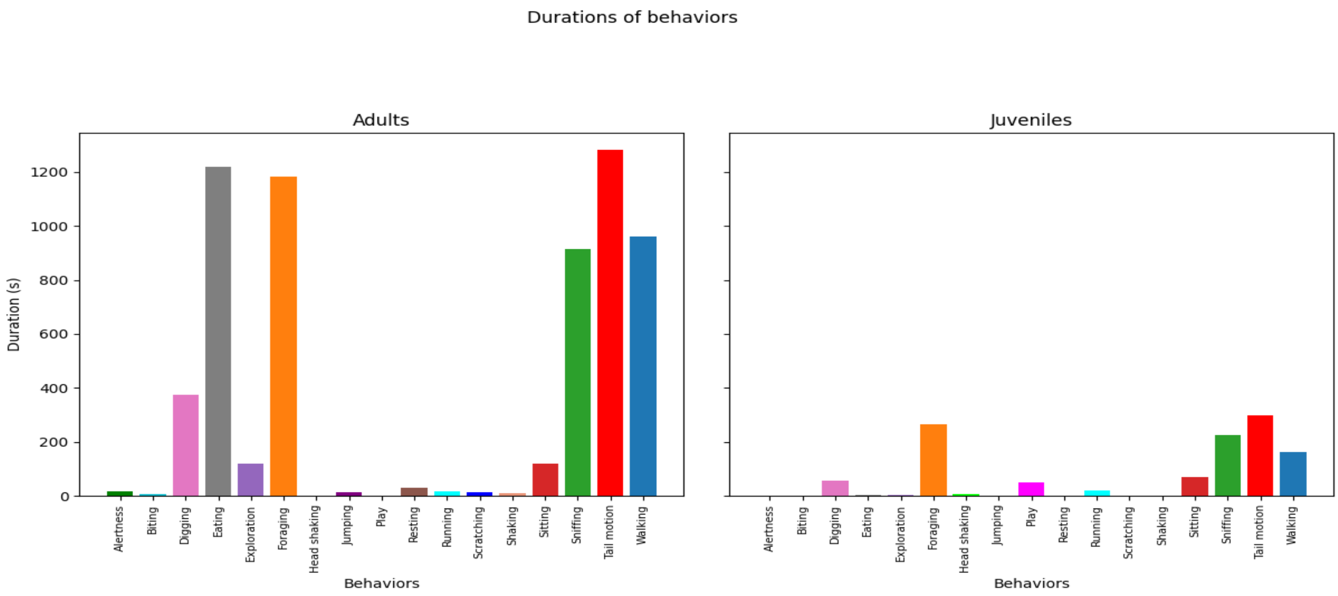

Figure 9 – Low Altitude (Social Behaviour): - duration of behaviours observed *in group living adults (left side) and juveniles (right side) at low altitude.*

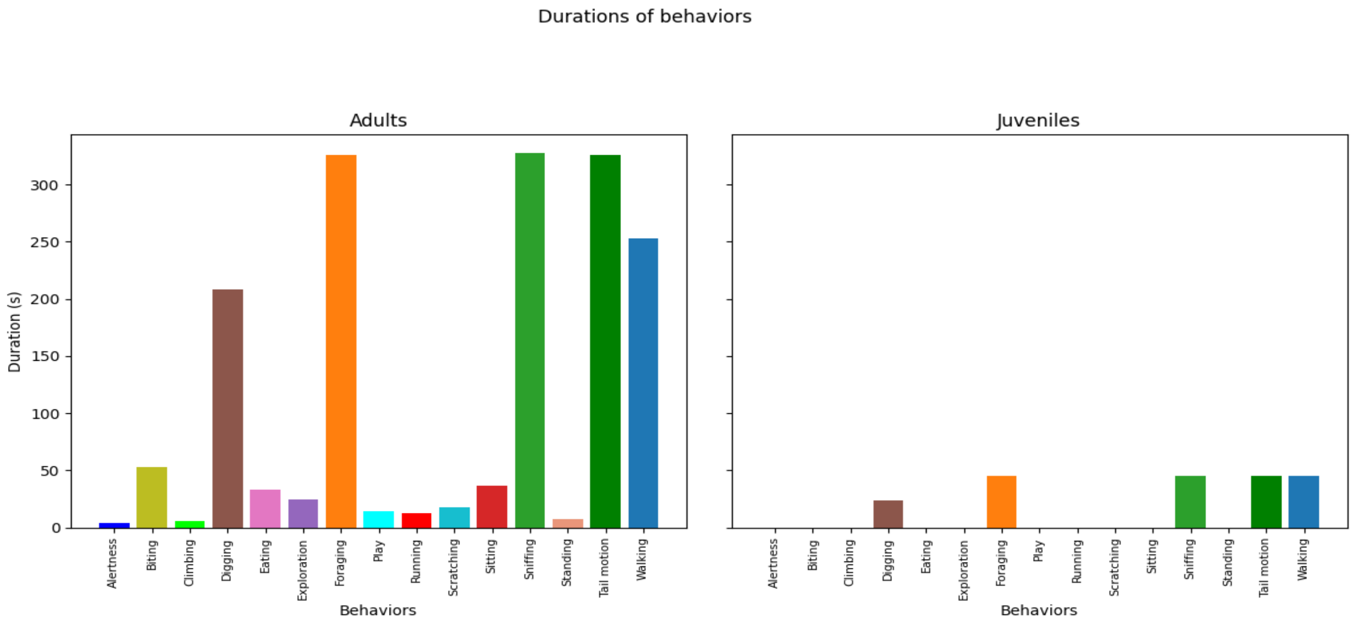

Figure 10 – High Altitude (Social Behaviour): - duration of behaviours observed *in group living adults (left side) and juveniles (right side) at high altitude.*

Total duration for adult social behaviours at low altitude was 1 hour 44 minutes and 19 minutes for juveniles social behaviours, whilst the total duration for adult social behaviours at high altitude was 27.5 minutes and 3.4 minutes for juveniles social behaviours. Foraging behaviour at low altitude was the longest timed behaviour, observed for 77% of the total video duration. Similarly, foraging behaviour at high altitude was the longest timed behaviour, observed for 95.4% of the total video duration. Chirping was recorded as a point event rather than state event, meaning no timed duration of behaviour.

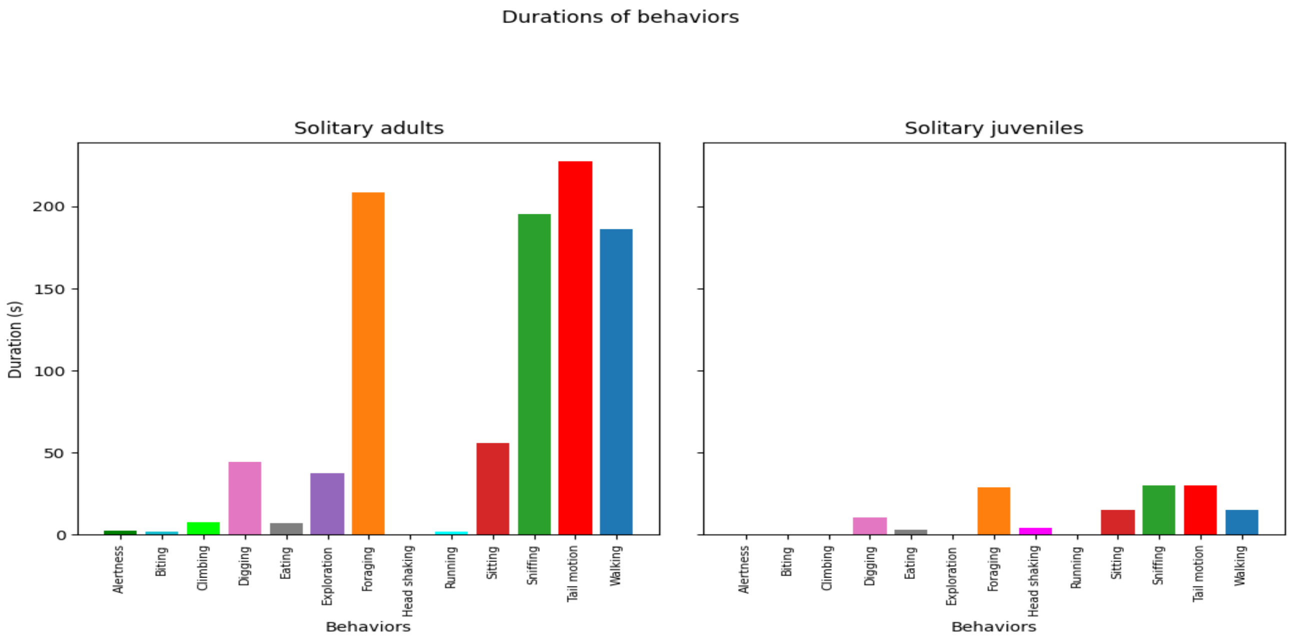

Figure 11 – Low Altitude (Asocial Behaviour): - duration of behaviours observed in solitary adults (left side) and juveniles (right side) at low altitude.

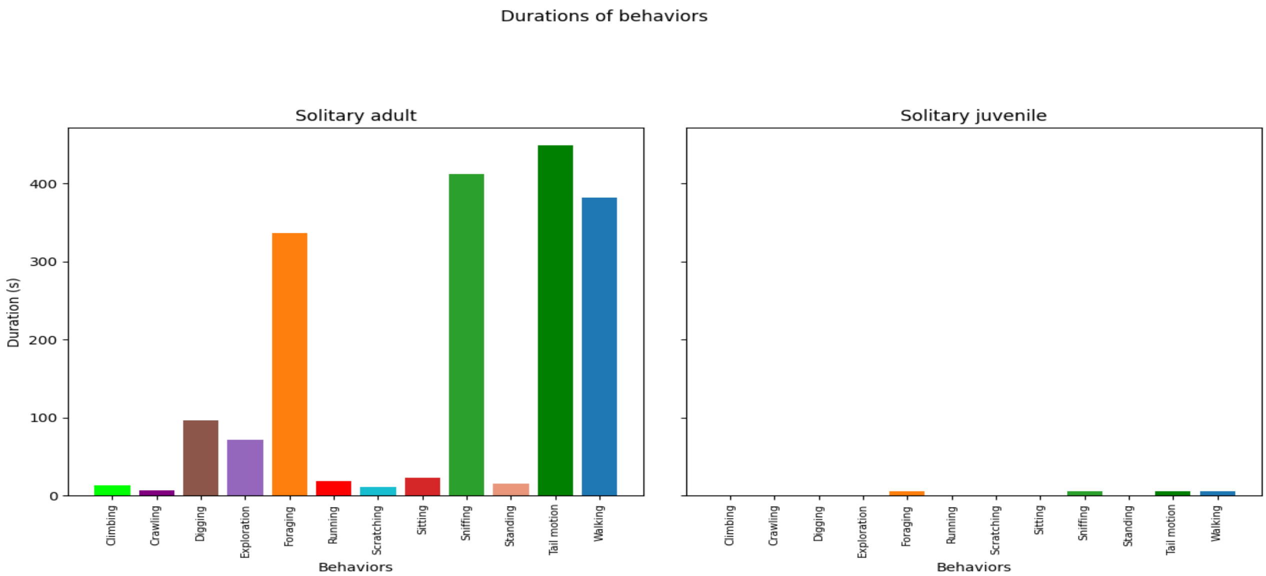

Figure 12 – High Altitude (Asocial Behaviour): - duration of behaviours observed in solitary adults (left side) and juveniles (right side) at high altitude.

Total duration for adult asocial behaviours at low altitude was 17 minutes and 2.5 minutes for juveniles asocial behaviours, whilst the total duration for adult asocial behaviours at high altitude was 30.5 minutes and 22 seconds for juveniles asocial behaviours. Foraging behaviour at low altitude was the longest timed behaviour, observed for 71% of the total video duration. Conversely, sniffing behaviour at high altitude was the longest timed behaviour, observed for 68% of the total video duration.

Within time budget analysis data, statistical differences can be discerned through a series of specific parametric tests.

Table 4 - Two-sample T-test assuming unequal variances tested for statistical difference of social behaviours observed across altitude.

High altitude social behaviour vs low altitude social behaviour	
Test for difference	***P-value***
occurrence of adult behaviours	*P(T<=t) two-tail = 0.014*
occurrence of juvenile behaviours	*P(T<=t) two-tail = 0.001*
total duration of adult behaviours	*P(T<=t) two-tail = 0.03*
total duration of juvenile behaviours	*P(T<=t) two-tail = 0.016*

Table 5 - Two-sample T-test assuming unequal variances tested for statistical difference of asocial behaviours observed across altitude.

High altitude asocial behaviour vs low altitude asocial behaviour	
Test for difference	***P-value***
occurrence of adult behaviours	*P(T<=t) two-tail = 0.10*
occurrence of juvenile behaviours	*P(T<=t) two-tail = 0.036*
total duration of adult behaviours	*P(T<=t) two-tail = 0.22*
total duration of juvenile behaviours	*P(T<=t) two-tail = 0.02*

**P values highlighted in red are non-significant.*

All *P values* were statistically significant, falling below the 0.05 significance level, except for two values highlighted in red. For social behaviours across altitude the alternate hypothesis was accepted, as altitude was shown to influence behaviour both in occurrence and duration (Table 4).

For juvenile asocial behaviours across altitude, the alternate hypothesis was accepted, as altitude was shown to influence behaviour in both occurrence and duration (Table 5). However, adult asocial behaviour was not statistically significant, therefore accepting a null hypothesis that altitude has no influence on the occurrence and duration of adult asocial behaviour.

Discussion

Effect of Altitude

A larger number of solitary coatis were observed at high altitude (68 in total), compared to low altitude (11 in total), whilst a larger number of coati bands (31 in total) were observed at low altitude, compared to high altitude (18 in total) (Table 2). Despite numerical differences in distribution, no statistical significance was found between the two samples, which is attributable to an extensive habitat range in the reserve (Roubert-Olive, 2018). At Cloudbridge, coatis are extensively distributed to access better food sources and to avoid predation, suggesting comprehending population abundance requires longer time in the field, with more locations for gathering data (Gompper, 1996). This rectified for a short-term study by altering the sampling design by acquiring more than two samples (e.g., more than one sample taken at high and at low altitude).

Behavioural variation was apparent across altitude, as seen with asocial coati behaviours of crawling, standing, and climbing that were only observed in solitary individuals at high altitude. Further, variation in foraging techniques was evident with tree-foraging observed only at high altitude. Higher abundance of foliage and denser tree cover makes the landscape at higher altitude more ideal for solitary individuals to express varied foraging methods aimed at obtaining food (Romp, 2019). Against the distinguished trend, one juvenile expressing asocial behaviour was observed at high altitude despite that juveniles are normally confined to social bands, rather than solitary movement at high altitude (Espinoza-García et al, 2014). One plausible explanation is in large bands adult coatis have been known to leave juveniles alone to scope areas for predators and food sources (Logan, 2013). In this case bolder juveniles without any confines that an adult would impose, will stray away from the band, which at a higher altitude can significantly lessen the chances of their survival (Gompper, 1997).

Tail movement is open to interpretation as a socially learned behaviour or a reflex instated by the environment (Di Blanco, 2006). In behavioural analysis, tail motion was categorised in two ways, an upright tail, and a downward tail. An upright tail was observed with adults helping juveniles to locate them when travelling through dense undergrowth, or when an individual was focussed on a threat in their environment (e.g., humans or predators) (Frehner, 2018; Gompper, 1996). A downward tail was observed in individuals climbing for balance and juveniles who are not fully developed into use of their tail, or individuals in a state of rest (Gompper, 1996).

Environmental Influences

Possessing behavioural traits to combat environmental variation and prolong evolutionary fitness is a requirement within remote, hostile landscapes, with ever-altering atmospheric conditions (Buchholz et al, 2019). Environmental influences like weather patterns can generate limitations within short term research conducted where there is a prolonged wet or dry season (Smith, 2021). At Cloudbridge it may be more difficult for coati bands to venture to higher altitudes during stormy seasons, where downpours can impact movement over the steep, rugged terrain (Romp, 2019). Future research comparing camera trap footage from the wet season and dry season could elucidate if climate plays a role in coati behaviour and distribution. Aside from the climate, diurnal activity of coatis, foraging during daytime and resting at night, conveys the influence that time of day has on behaviour (Frehner, 2018). Ocelots *(Leopardus pardalis),* one of the primary predator threats to coatis at Cloudbridge, are more commonly found at higher altitude, constraining large bands with many juveniles to habituate at lower altitude (Romp, 2019). This increases competition for limited food sources between rival bands, and perhaps a reason why solitary individuals are more willing to risk proceeding to higher altitude where there is less competition for food.

Camera Traps within the Sample Design

Animal behaviour like any other environmental field, must be measured with clear precision and accuracy to obtain valid results (Burton et al, 2015). In rainforest environments like Cloudbridge, behaviour of elusive species (e.g., Baird's Tapir *Tapirus bairdii)* is unable to be documented without employing a camera trapping method, that limits human interaction (Troillet et al, 2014). Moreover, Cloudbridge is sprawling in size, so acquiring data requires greater effort when employing in person observational fieldwork. Thus, applying a camera trap method can reduce long set up times and labour efforts, which are associated with in person observational set ups, resulting in more exhaustive quantitative data that will advance research aims (Brandis et al, 2014). Using camera traps to document White-nosed Coatis aids in developing advanced understanding of the environment in which the species evolved in, while providing more informed decisions relating to protection for a species that could gradually become endangered (Berry, 2021). Additionally, recognising the increasing risks to diverseness within a habitat, can instigate awareness to unravelling the apparent zoological and distinctive components that assemble species affluence and equality (Silliman, 2011; Mooney et al, 2009).

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