Microhabitat Preference of the White-nosed Coati (*Nasua narica*) in a Costa Rican Cloud Forest

Patrícia Isabel Marçalo Nicolau

SID: 1741470

BSc (Hons) Animal Behaviour

Faculty of Science and Engineering

School of Life Sciences at Anglia Ruskin University

April 2022

ABSTRACT

Habitat fragmentation has been a significant issue affecting the dynamics of neotropical mammals in their habitats. Cloud forests are one of the most fragile ecosystems on Earth that hold high amounts of endemism and biodiversity and are strongly impacted by fragmentation. Different successional forest stages affect the habitat use of species inhabiting them, and microhabitat factors have a great influence on this. In this study, the occurrence of white-nosed coatis (*Nasua narica*) was assessed, using camera traps, in a montane cloud forest (Cloudbridge Nature Reserve). Habitat preference was assessed by analysing the relationship between the microhabitat variables (diameter at breast height (DBH), canopy coverage, tree height and tree abundance) with the frequency of sightings of coatis. The results showed that white-nosed coatis are mainly seen in Natural Regrowth Forest. None of the results for the variables in relationship with the sightings was significant, implying that the habitat variables did not strongly affect their occurrence within the forest. Canopy coverage was the variable that showed the strongest positive relationship with the frequency of sightings.

Table of Contents

INTRODUCTION

Neotropical montane cloud forests are characterized by continued cloud cover at vegetation height and are one of the most fragile and threatened ecosystems on the globe (Bubb *et al*., 2004). Accounting for 2.5 percent of all tropical forests and covering only 0.4% of the planet's land surface, these unique ecosystems hold around 16% and 20% of vertebrate and plants species, correspondingly, worldwide (Myers *et al*., 2000). In accordance with these values, they are considered biodiversity hotspots, with significant levels of endemism and a variety of vulnerable species. (Ray *et al*., 2006). Despite their biological importance, these ecosystems are highly endangered by deforestation and habitat fragmentation for cattle ranching, mainly (Holl *et al*., 2000). Adding to this, due to low daylight temperatures and their prevalence in mountain ranges, neotropical cloud forests have a very slow and delayed regeneration process, increasing the vulnerability of these ecosystems (Gomes *et al*., 2008). According to previous studies, a successional forest requires a minimum of 80 years to reach a structure that mimics a primary forest in terms of canopy maximum height and basal area. However, it can take can more than a century for it to recover in terms of species presence (Gomes *et al*., 2008).

The fragmentation of the neotropical cloud forests has a great impact on the biodiversity they hold, with more than a third of the species disappearing when these environments are destroyed. Because of this, conservation biology needs to focus not only on protected areas but also in areas that are managed (Bogoni *et al*., 2013). Land that has been converted for cattle ranching and agriculture, is often abandoned when it is not valuable anymore, giving it the opportunity to regrow (Romero *et al*., 2016). Therefore, younger forests have been becoming a significant feature of neotropical landscapes. Neotropical mammals are crucial elements of these systems and take an important part in the complex interactions of tropical food chains (Cuarón, 2000). Mesoherbivores, like the white-nosed coati act as seed dispersers, which promotes gene flow of plants, especially in fragmented forest habitats (Alves-Costa and Eterovick, 2007). This dispersal by mammals ultimately affects floristic composition in successional forests as well as plant demography (Hanson *et al*., 2006).

Individuals make several decisions during their activities, such as feeding, escaping predators, seeking refuge, and selecting a mate, which all influence habitat selection. For instance, coatis choose trees with a wider canopy to build their nests, which highlights the importance of certain factors of their microhabitats (in this case, arboreal structure) for their activities and reproduction. Coatis build their nests in trees for resting and for their young (Olifiers *et al*., 2009). Consequently, habitat use does not generally happen at random, since individuals usually prefer patches with resource availability (Prevedello *et al*., 2010). Several habitat selection studies focus on live trapping as a method to assess individuals' preference, using the location of the capture as a measure to define habitat use (Coppeto *et al*., 2006). However, this is not the most accurate method to evaluate habitat preference and use. Another ecological approach to study preference of habitat is the investigation of microhabitat use and its structure (de Lima *et al*., 2010). Especially in fragmented habitats, microhabitat preference can be a significant influence on the capacity of mammals occupying these ecosystems (Püttker *et al*., 2008). Microhabitat studies have been found to have considerable effects on species presence (Damalgro and Vieira, 2005) and can also provide information on the quality of each successional stage of fragmented forest and if these hold all the requirements for the species living in them.

For this research, the occurrence of white-nosed coatis in different successional stages of a montane cloud forest in Costa Rica is being analysed using camera traps.

Furthermore, microhabitat variables are being analysed on how they influence the frequency of coatis' sightings. For the purpose of this study, coatis' sightings were analysed throughout the different forest types, hypothesising that there would be a preference for one forest type. To determine their preference for a forest type based on the microhabitat factors, it was hypothesised that diameter at breast height (DBH), tree height, canopy coverage and tree abundance would have a strong positive relationship with the sightings of the white-nosed coatis, meaning the higher each one of the parameters, the higher would be the number of sightings.

MATERIALS & METHODS

Study Area

This research was conducted in Cloudbridge Nature Reserve in San Gerardo de Rivas, Pérez Zeledón, Costa Rica (09°50'N, 83°55'W) (Figure 1). Cloudbridge is a privately owned nature reserve in the heart of the Talamanca Mountain range, connected to the Chirripó National Park, and it covers 200 hectares of successional forest (Taylor and White, 2007). Before purchase, the land was used to agriculture and cattle pasture and since 2002, Cloudbridge has been committed to the conservation of the cloud forest, with reforestation efforts and education outreach programmes (Cloudbridge Nature Reserve, n.d.). Furthermore, the nature reserve serves as a bridge for species movements between Talamanca Nature Reserve and Chirripó National Park and houses over 400 species of vertebrates (Cloudbridge Nature Reserve, n.d.).

Figure 1: Location of Cloudbridge Nature Reserve (Google Maps, 2022).

Study Species

White-nosed Coatis (*Nasua narica*) belong to the family Procyonidae (Trovati *et al*., 2009). *N. narica* is an omnivorous semi-arboreal mammal, considered to be one the most common mammals in neotropical forests (Pérez-Irineo and Santos-Moreno, 2016). They have been documented, mainly for their ecological plasticity, as they are frequently present in areas with fluctuating degrees of disturbance (Hernández-Díaz *et al*., 2012). In Cloudbridge Nature Reserve, coatis were one the most frequently sighted animals in the camera traps.

Data Collection

1.1 <u>Camera Traps</u>

For this research, eight cameras were used for collecting data on the presence of white-nosed coatis. All the cameras were placed preciously to the project, as camera-trapping was an on-going project at Cloudbridge Nature Reserve, and they were not purposely changed for this research. The cameras were set in 15 different locations, covering three different forest types (7 in Naturally Regenerated Forest, 5 in Primary Forest and 3 in Planted Forest). These were situated just off trail to avoid human interference (only one camera was placed in a trail). The deployment time of the cameras was two weeks. In the same time frame, the memory cards of the cameras were taken out and the data was inserted in Cloudbridge's database for their camera trapping project.

1.2 Vegetation Surveys

In order to analyse the relationship between microhabitat factors and the species' habitat preference, vegetation surveys were performed in in the different types of forest within the reserve (Figure 2). For every CT location, a vegetation survey was conducted. In total, 15 surveys were done, and 83 trees were measured regarding their diameter at breast height (DBH) and height.

In each CT location, a plot of ($25m^2$) was defined, having the CT as a middle point. From that middle point, 5m were measured in each cardinal point and then marked with sticks and flagging tape to define the perimeter. DBH, tree height and canopy coverage were measured and calculated as well as tree abundance.

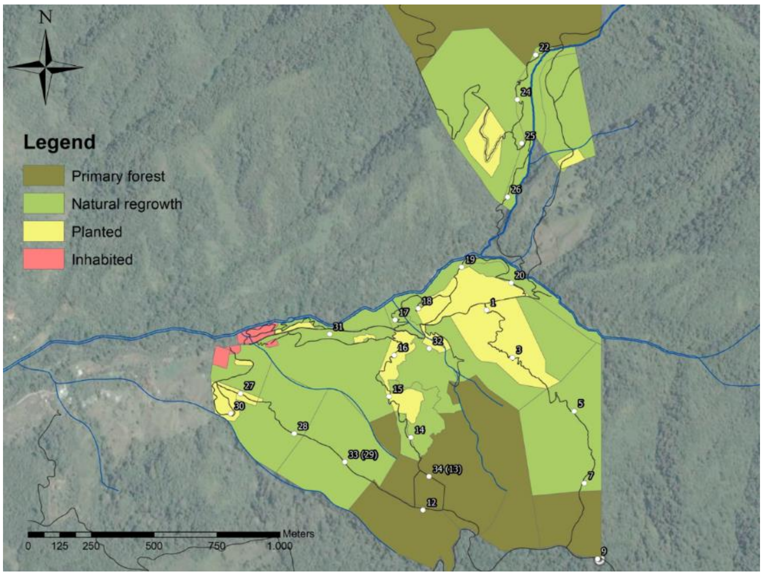

Figure 2: Vegetation map showing the three different successional forest stages: Primary Forest, Natural Regrowth and Planted Forest (Cloudbridge Nature Reserve, n.d.).

1.2.1 DBH

Tree size was determined by measuring the tree's diameter at 1.40 meters from the ground (breast height of an average human). To measure the DBH, measuring tape was used to measure the 1.40 m point. Using that point as a reference, the DBH was measured with a diameter tape. If a tree was too wide, a normal measuring tape was used, which indicated the circumference of the tree that was later converted to the diameter. When the main stem divided into two or more stems below the 1.40 m mark, all the stems were measured at the DBH height and counted as different trees. When the main stem separated into two or more stems above the 1.40 m mark, the wider stem was measured at DBH height and counted as one tree. If half of the tree or more was within the plot, the tree was considered to be inside of it and therefore measured. Only trees with a DBH equal or higher than 10cm were accounted for the study.

1.2.2 Tree Height

To measure tree height, the material used was a clinometer with a 15 and 20m scale. Firstly, an estimate of the height of the tree would be gone to decide how far from the tree the top of the canopy was seen (either 15 or 20m). Then, using a measuring tape, the chosen distance would be walked away from the tree. From this point, using the clinometer, the observer would look up to the treetop and take a note of the value on the clinometer and then look at the tree base and take note of value shown. Depending on the slope of the ground, calculations of the tree height were done (Figure 3).

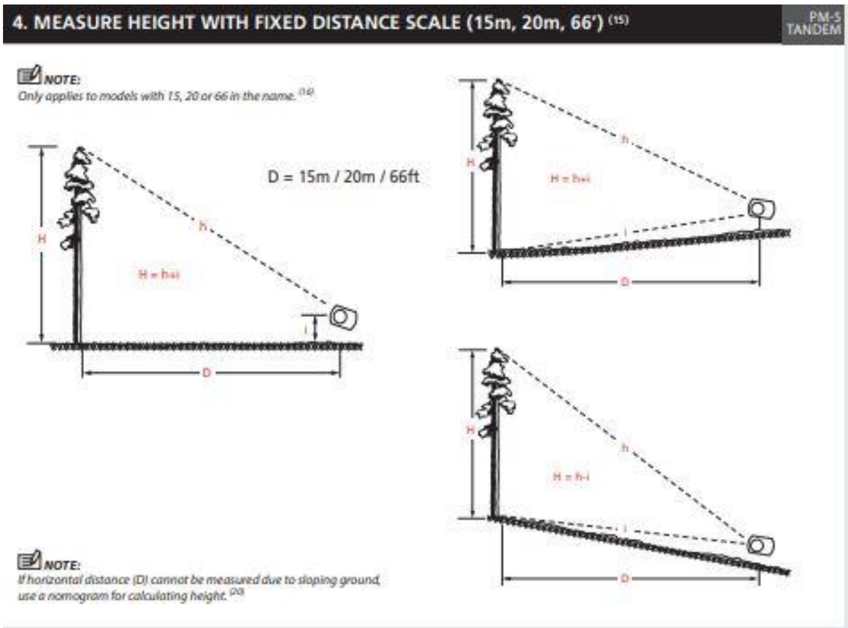

Figure 3: Instructions of tree height measurement (Suunto, 2022).

1.2.*3* Canopy coverage

In all 15 plots, the canopy coverage was measured using two different methods. Despite the method used, one reading per method was done in each cardinal point, 5m from the CT point, and then the average of the canopy coverage was calculated for each plot. The first readings of the canopy coverage were taken by making use of the CanopyApp, an app developed by the University of New Hampshire (2018). The second method applied to measure this factor was with the use of a spherical densiometer. This was done by pointing the device up, towards the sky, and counting every point of the grid of the densiometer that was covered by vegetation (Figure 4).

After counting the points, the number would be timed by 1.04 to give the percentage of canopy coverage.

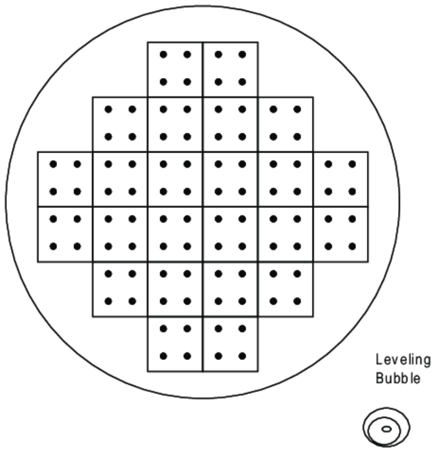

Figure 4: Diagram of a spherical densiometer (Holmes et al., 2015).

1.2.*3* Tree Abundance

To describe tree abundance, only alive trees were accounted. All the trees that fitted the parameters required for the research were counted per plot to determine tree abundance.

Data analysis

To statistically analyse the data collected a Shapiro-Wilk test was performed in order to determine the normality of the data. After checking for normality, a one-way chi-square test was preformed to analyse the difference of coatis' sightings within the different types of forest. To determine the strength of the relationship between the sightings and the microhabitat variables, Pearson correlation tests were conducted for each variable. All the statistical analysis were performed using IBM SPSS Statistics for Windows, Version 28.0.1 v3.

RESULTS

For this research, a total of 336 sightings of coatis were registered within the tree different types of forest. Regarding the microhabitat variables, in Natural Regrowth Forest (the most predominant type of forest in the reserve), a total of 34 trees were measured regarding their height and diameter at breast height; in Planted Forest (the least predominant type of forest), a total of 11 trees were measured; and in Primary Forest, the type of forest with highest tree abundance, a total of 37 trees were measured. A Shapiro-Wilk test was performed to determine whether the data was normally on non-normally distributed. The data for the Coati sightings was determined non-parametric (Shapiro-Wilk: W= 0.820, df= 15, p= 0.007). According to the Shapiro-Wilk: W= 0.939, df= 15, p= 0.372, the data for DBH was considered parametric. For the tree height data, the results of the Shapiro-Wilk: W= 0.944, df= 15, p= 0.433, showed the data was parametric. It was decided the data was parametric for the canopy coverage data due to the results of the Shapiro-Wilk: W= 0.965, df= 15, p= 0.783. According to the Shapiro-Wilk: W= 0.928, df= 15, p= 0.252, tree abundance data was also parametric, due to its normal distribution.

The One-way Chi-square test to determine if there was a difference in coati sightings throughout the different types of forest proved to be significant (One-way Chi-square: X^2_2= 75.661, N= 336, p= 0.000). The result of the test supports the hypothesis that coatis have a preference on forest type. Although the number of sightings was much higher in Natural Regrowth Forest, the mean of coatis' sightings was higher in Planted Forest (Figure 5). A total of 179 sightings were registered in Natural Regrowth Forest, where 7 camera traps were installed. The mean number of sightings in this type of forest was 25.6. In Primary Forest, 49 sightings were recorded in 5 cameras. The mean number of sightings was 9.8. In Planted Forest, there were 108 coatis' sightings in 3 cameras. The mean number of sightings for this forest type was 36 (Figure 6).

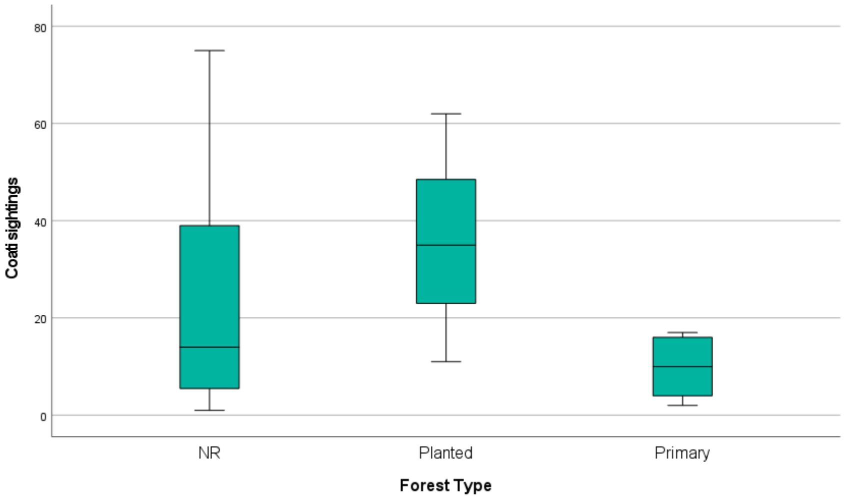

Figure 5: Coati sightings across three types of forest: Natural Regrowth Forest, Planted Forest and Primary Forest (n_{NR}=179, $n_{Planted}$= 108, $n_{Primary}$=49). The interquartile range is exemplified by the green box, the median is represented by the black line inside the box and the whiskers show the lowest and highest value for each forest type.

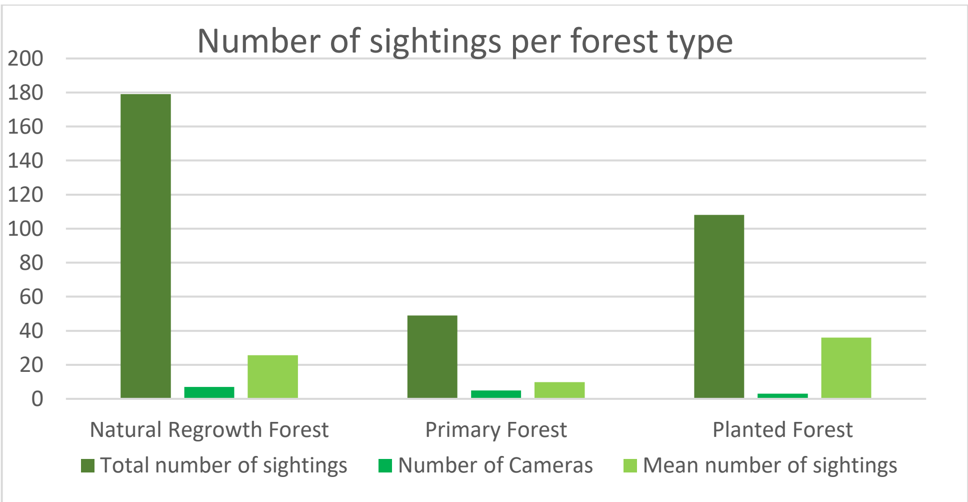

Figure 6: Number of sightings per type of forest, including the total number of sightings, the number of cameras and the mean number of sightings per type forest type.

A Pearson Correlation test was performed to determine the strength of the relationship between coatis' sightings and the DBH of the trees. The results showed to be non-significant (Pearson Correlation: r_{13}= 0.112, N= 15, p= 0.691). Although non-significant, there is a positive relationship between the frequency of coatis and the DBH of trees, meaning that the bigger the diameter of trees, the higher is the number of sightings. However, this is not a very strong relationship (Figure 7).

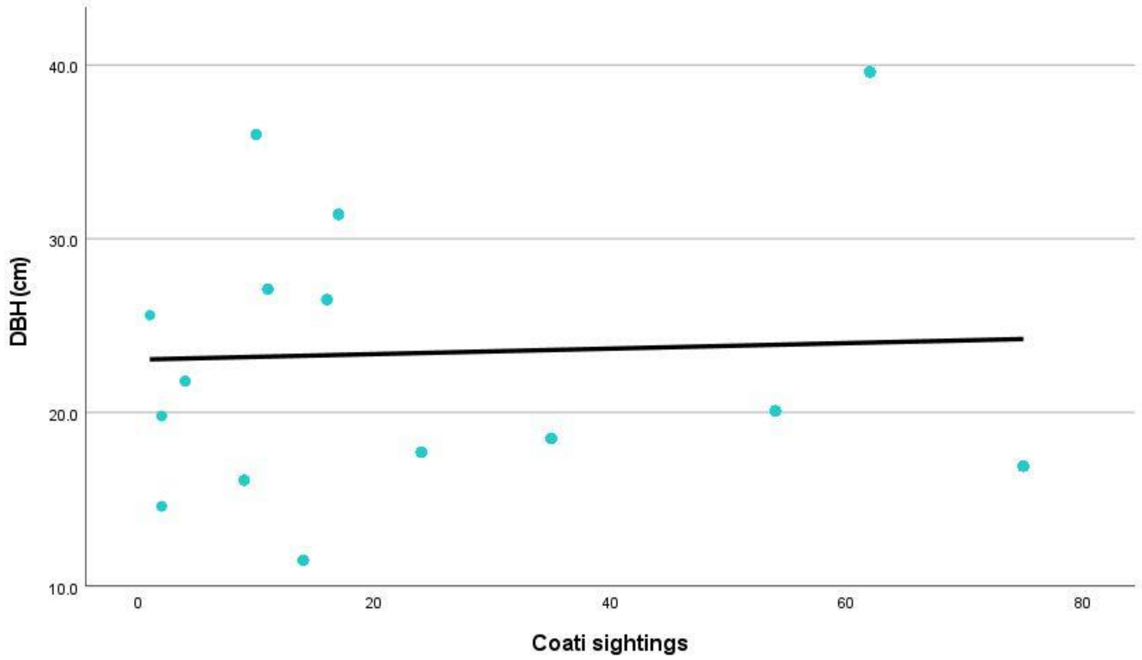

Figure 7: Relationship between coatis' sightings and DBH (cm).

The results for the relationship strength between coatis' sightings and tree height showed to be non-significant, rejecting the hypothesis that the higher the trees, the higher would the number of sightings be (Pearson Correlation: r_{13}= -0.214, N= 15, p= 0.444). While the hypothesis was rejected, there is a negative relationship between the frequency of coatis and the tree heigh, suggesting that the number of sightings increases when the height of the trees decreases. However, the relationship is not strong enough to be clearly seen (Figure 8).

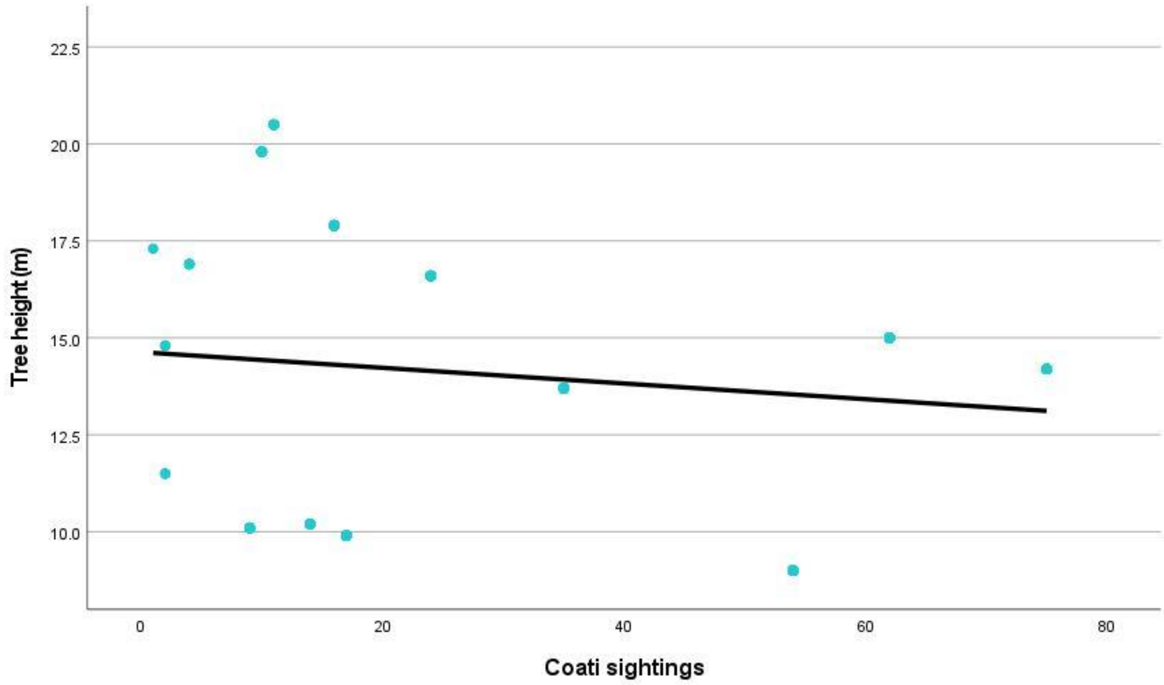

Figure 8: Relationship between coatis' sightings and tree height (m).

The Pearson Correlation test measuring the relationship strength between coatis' sightings and canopy coverage was also non-significant. Once again, rejecting the hypothesis that the higher the percentage of canopy coverage, more sightings of coatis would occur (Pearson Correlation: r_{13}= 0.377, N= 15, p= 0.166). Whilst the hypothesis was rejected, a positive relationship between canopy coverage and coatis' frequency is present, implying that the higher the percentage of coverage, the more sightings of coatis would exist. The relationship is somewhat visible, indicating that this variable holds some responsibility for the presence of coatis in the habitat that has a higher canopy coverage percentage (Figure 9).

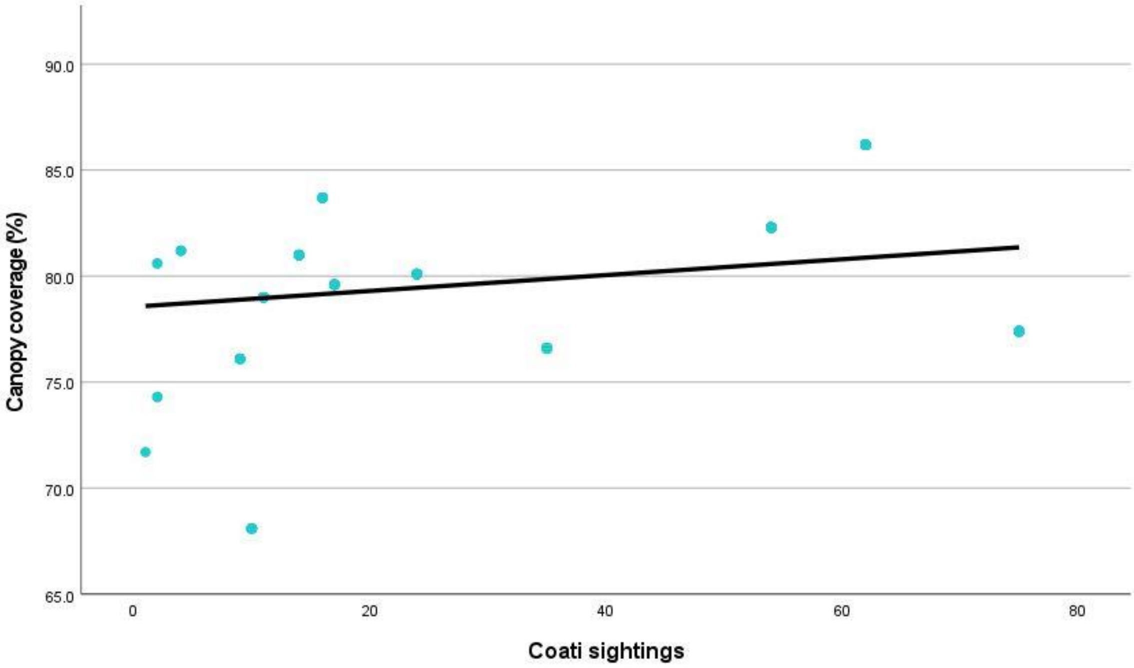

Figure 9: Relationship between coatis' sightings and canopy coverage (%).

The relationship between coatis' sightings and tree abundance showed to be non-significant, according to the results of the Pearson Correlation test, rejecting the hypothesis that the higher the number of trees per plot, the higher the number of coatis seen (Pearson Correlation: r_{13}= -0.078, N= 15, p= 0.783). While the hypothesis was rejected, there is a negative relationship between the frequency of coatis and tree abundance, indicating that the number of sightings increases when the abundance of trees decreases. However, the relationship is not strong enough to be clearly seen (Figure 10).

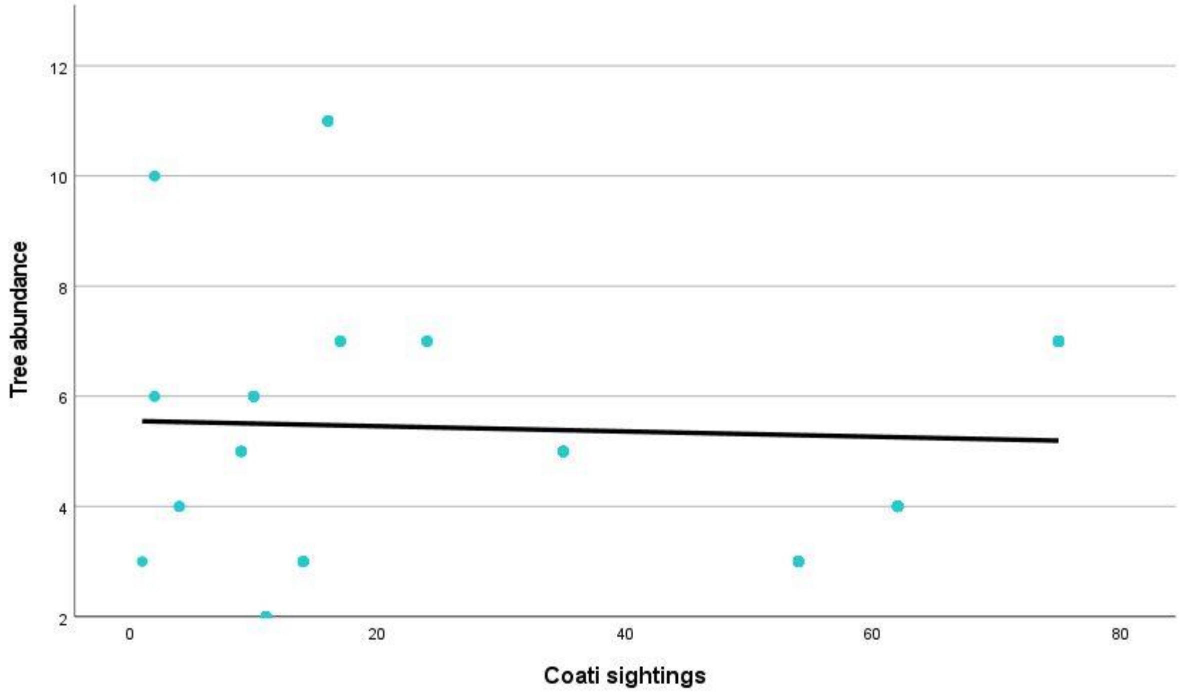

Figure 10: Relationship between coatis' sightings and tree abundance.

DISCUSSION

Mammalian habitat use research is critical for understanding the factors that drive their distribution and abundance. Animals selectively occupy areas where resources are available, therefore habitat usage does not happen at random (Garshelis, 2000). Successional forests vary substantially in abiotic and biotic forests within their successional stages, due to forest age and the history of land use (Guariguata and Ostertag, 2001). These differences include above-ground biomass, composition and richness (de Camargo *et al*., 1999). A combination of these differences in successional forests would indicate differential responses from different animals. Generally, research has found that primary forests hold greater rates of species richness and different community structures than secondary or planted forests (Bogoni *et al*., 2013). However, in the present research white-nosed coatis had the highest number of sightings in Natural Regrowth Forest and the highest mean of sightings in Planted Forest. This could be related to the altitude at which the Primary Forest was more present, since species richness tends to decrease towards higher altitudes (Bogoni *et al*., 2013), or the availability of resources (Garshelis, 2000). It is important to mention that the number of cameras changed throughout the forest types within the reserve. The lack of homogeneity in numbers throughout the locations might have affected the results. Although studies on coatis' microhabitat use and preference are scarce, similar studies have been conducted on other species. Research has shown that the ring-tailed coati (*Nasua nasua*) displays a preference for intermediate forest coverage (Goulart *et al*., 2009), which would parallel to Natural Regrowth Forest in the present study.

This study showed a weak positive correlation between coatis' sightings and diameter at breast height. In Natural Regrowth Forest, where the higher number of sightings occurred, the mean DBH was 17.12 cm. Even though tree species were not considered for this study, research conducted by Beisiegel and Mantovani (2006) showed that Bromeliads with a DBH between 10-20cm had the higher number of locusts in them, therefore, forest with the highest abundance of Bromeliads with a DBH within those values was preferred, as locusts are part of coatis' diet (Valenzuela, 1998).

Canopy coverage was the microhabitat condition that revealed the strongest positive relationship with coatis' sightings. Jennings et al. (1999) described that the coverage provided by the canopy controls the quantity and quality as well as the geographical and temporal luminosity distribution. It also determines different levels of humidity, temperature and soil humidity conditions. As a result, canopy coverage is the most important driver of a forest's internal microhabitat due to its influence on the growth and development of seedlings, which is responsible for the floristic structure of an ecosystem. Additionally, certain microclimatic variations such as temperature or precipitation (as a result of changes in the microhabitat factors, such as canopy coverage) act together in order to establish resources and favourable conditions for plant growth, which will ultimately impact the local fauna (Bogoni *et al*., 2013). This positive relationship between canopy coverage and coatis' sightings could also be explained by the fact that coatis travel along the canopy when foraging for food. Adding to this, it is also known that coatis build the nest for their young in the canopy (Gompper, 1997). A study by Dalmagro and Vieira (2005) also found a relationship between the percentage of canopy coverage and the abundance of the Montane grass mouse justified by the fact that canopy coverage tends to decrease the probability of individuals being seen by predators.

Tree abundance and tree height were the two variables that showed a negative relationship with the sightings of the coatis. Tree abundance showed a very weak relationship, and the result was non-significant. This could possibly be because, although coatis do spend a lot of their time in trees, they do not solely depend on trees to feed, foraging mostly on leaf-litter for invertebrates (Hirsch *et al*., 2013). Regarding tree height, the results implied that as tree height decreased, the number of sightings increased. Once again, this can be linked to the inconsistency in the number of surveys. In Planted Forest, where the mean number of sightings is the highest, only 3 surveys were conducted and only 11 trees were measured, due to the absence of trees with a DBH equal or higher than 10cm. However, in Natural Regrowth Forest, 7 surveys were done and a total of 34 trees were measured. Literature assessing the impact of tree height and tree abundance on white-nosed coatis has not been done.

It is worth noting that the number of surveys conducted was not consistent throughout the different forest types, skewing the results of the variables when in correlation with the coati sightings. The sample size was also small, making reaching a conclusion more challenging. This being stated, the study of the impact of microhabitat variables on coatis' preference for a forest type had no significant reaults, and that might indicate that the forest has been recovering to a point where species no longer reveal habitat preference. The fact that white-nosed coatis have very large home ranges and considerably variable habitat occupation (Bogoni *et al*., 2013), might also be a possible explanation for the absence of preference for a specific type of forest. However, when looking into the camera trap images, white-nosed coatis showed to be more present in Natural Regrowth, where the vegetation has an intermediate coverage. This could be due to its habitat requirement, as this is mostly a forest dwelling species (Cáceres *et al*., 2007). Coatis have difficulty in climbing and descending smooth, vertical trunks of trees with larger diameters; trees with these characteristics are commonly found in Primary Forest, which could be an explanation for high number of sightings in Natural Regrowth Forest (Goulart *et al*., 2009). Although predator presence was not accounted for this study, it could also have an impact on the habitat preference of white-nosed coatis. Coatis' predators, such as the ocelot and the puma (Pérez-Irineo and Santos-Moreno, 2016) were often seen in Primary Forest within the reserve, which could explain their absence in Primary Forest. For future research, looking into tree species distribution in different successional stages of forest would be interesting, specially taking into consideration Bromeliads, as these seem to be one of the preferred species to forage on (Beisiegel and Mantovani, 2006) as well as look into food availability. Predator presence would also be an interesting factor to analyse in the future.

ACKNOWLEDGMENTS

I want to take this section to acknowledge everyone that was somehow involved in this project with me, whether they were involved academically or not. Firstly, I would like to thank my supervisors Olivia Norfolk and Philip Pugh. Olivia Norfolk was huge support during this process, from answering to all the doubts I had during this project to supporting me emotionally and guaranteeing I was taking care of myself while in Costa Rica. To Philip Pugh, I want to thank for taking over my project once Olivia left.

I want to thank to all the people from Cloudbridge Nature Reserve. Paula Pebsworth, the scientific director, for always being available to talk to me, for providing me with all the essential materials and for ensuring I was not missing anything. To Casey McConnell, the director of the reserve, for making my stay there so pleasing and easy and ensure I got the best experience I could have possibly imagined. Last but not least, to all the volunteers and research assistants for helping me collecting the data, even in the tougher areas. Thank you to all of you for making this project possible.

I could not be more appreciative of my family support. My mother and my stepfather for listening to me, even when they did not understand the topic, for believing in me during the times I did not have the strength and for raising me to be a woman that accomplishes everything she sets her mind to. I also want to thank my managers, Aleks and Dave. To Aleks for worrying and for being so flexible and caring, always making sure I was doing well; and to Dave for asking me a million questions every time, just to make sure I knew exactly what I was doing and for celebrating my academic achievements with me. To my housemates, Patrícia, Tiago and Miguel for understanding my absence from the house and for making sure I was able to separate my academic duties from my relaxing space. To Duarte for motivating me daily, even in Portugal. To Sushi, for inspiring me, for guaranteeing I took breaks, for supporting me and for believing in me. Lastly, to Catarina, Tânia, Luz, Isabel, Marta, Rita, Pedro, Cepêda Marvin and Cosmelli for making the endless nights seem less impossible and for always showing support for each other. It was a true pleasure going through this with you all and I would repeat it all again if I had to. You made all of this seem a piece of cake and for that I am eternally grateful.

REFERENCES

Alves-Costa, C. and Eterovick, P., 2007. Seed dispersal services by coatis (*Nasua nasua*, Procyonidae) and their redundancy with other frugivores in southeastern Brazil. *Acta Oecologica*, 32(1), pp.77-92.

Augusto Prevedello, J., Garcia Rodrigues, R. and Monteiro-Filho, E., 2010. Habitat selection by two species of small mammals in the Atlantic Forest, Brazil: Comparing results from live trapping and spool-and-line tracking. *Mammalian Biology*, 75(2), pp.106-114.

Beisiegel, B.M. and Mantovani, W., 2006. Habitat use, home range and foraging preferences of the coati *Nasua nasua* in a pluvial tropical Atlantic Forest area. *Journal of Zoology*, 269, pp.77-87.

Bogoni, J., Bogoni, T., Graipel, M. and Marinho, J., 2013. The Influence of Landscape and Microhabitat on the Diversity of Large- and Medium-Sized Mammals in Atlantic Forest Remnants in a Matrix of Agroecosystem and Silviculture. *ISRN Forestry*, 2013, pp.1-13.

Bubb, P., May, I., Miles, L., Sayer, J., 2004. Cloud Forest Agenda. UNEP-WCMC, Cambridge, UK. [online] Available at: <http://www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series/20.html > [Accessed 11 February 2022].

Cáceres, N., Casella, J., Vargas, C., Prates, L., Tombini, A., Goulart, C. and Lopes, W., 2007. Distribuição geográfica de pequenos mamíferos não voadores nas bacias dos rios Araguaia e Paraná, região centro-sul do Brasil. *Iheringia. Série Zoologia*, 98(2), pp.173-180.

Cloudbridge Nature Reserve in Costa Rica. n.d. *Welcome to Cloudbridge! - Cloudbridge Nature Reserve in Costa Rica*. [online] Available at: <http://www.cloudbridge.org/> [Accessed 11 February 2022].

Coppeto, S., Kelt, D., Van Vuren, D., Wilson, J. and Bigelow, S., 2006. HABITAT ASSOCIATIONS OF SMALL MAMMALS AT TWO SPATIAL SCALES IN THE NORTHERN SIERRA NEVADA. *Journal of Mammalogy*, 87(2), pp.402-413.

Cuarón, A. D., 2000. A Global Perspective on Habitat Disturbance and Tropical Rainforest Mammals. *Conservation Biology*, 14(6), pp.1574-1579.

Dalmagro, A. and Vieira, E., 2005. Patterns of habitat utilization of small rodents in an area of Araucaria Forest in Southern Brazil. *Austral Ecology*, 30(4), pp.353-362.

De Camargo, P., Trumbore, S., Martinelli, L., Davidson, E., Nepstad, D. and Victoria, R., 1999. Soil carbon dynamics in regrowing forest of eastern Amazonia. *Global Change Biology*, 5(6), pp.693-702.

Garshelis, D.L., 2000. Delusions in habitat evaluation: measuring use, selection, and importance. In: Boitani, L., Fuller, T.K. (Eds.), *Research Techniques in Animal Ecology*: Controversies and Consequences. Columbia University Press, New York, pp.111-164.

Gomes, L., Oostra, V., Nijman, V., Cleef, A. and Kappelle, M., 2008. Tolerance of frugivorous birds to habitat disturbance in a tropical cloud forest. *Biological Conservation*, 141(3), pp.860-871.

Gompper M.E., 1997. Population ecology of the white-nosed coati (*Nasua narica*) on Barro Colorado Island, Panama. *Journal of Zoology*, 241(3),pp.441–455.

Goulart, F., Cáceres, N., Graipel, M., Tortato, M., Ghizoni, I. and Oliveira-Santos, L., 2009. Habitat selection by large mammals in a southern Brazilian Atlantic Forest. *Mammalian Biology*, 74(3), pp.182-190.

Guariguata, M. and Ostertag, R., 2001. Neotropical secondary forest succession: changes in structural and functional characteristics. *Forest Ecology and Management*, 148(1-3), pp.185-206.

Guilherme Trovati, R., Alves de Brito, B. and Maurício Barbanti Duarte, J., 2009. Habitat use and home range of brown-nosed coati, *Nasua nasua* (Carnivora: Procyonidae) in the Brazilian Cerrado biome. *Revista de Biología Tropical*, 58(2).

Hanson, T., Brunsfeld, S. and Finegan, B., 2006. Variation in Seedling Density and Seed Predation Indicators for the Emergent Tree *Dipteryx panamensis* in Continuous and Fragmented Rain Forest. *Biotropica*, 38(6), pp.770-774.

Hernández-Díaz, M., Ramírez-Barajas, P., Chávez, C., Schmook, B. and Calmé, S., 2012. Presencia y abundancia relativa de carnívoros en una selva dañada por el huracán Dean (2007). *Revista Mexicana de Biodiversidad*, 83(3).

Hirsch, B., Tujague, M., Di Blanco, Y., Di Bitetti, M. and Janson, C., 2013. Comparing capuchins and coatis: causes and consequences of differing movement ecology in two sympatric mammals. *Animal Behaviour*, 86(2), pp.331-338.

Holl, K., Loik, M., Lin, E. and Samuels, I., 2000. Tropical Montane Forest Restoration in Costa Rica: Overcoming Barriers to Dispersal and Establishment. *Restoration Ecology*, 8(4), pp.339-349.

Holmes, J. A., M. J. Johnson, C. L. Lauver, J. R. Norris, A. E. C. Snyder, and L. P. Thomas, 2015. Habitat-based bird community monitoring protocol for the Southern Colorado Plateau Network. Natural Resource Report NPS/SCPN/NRR—2015/1041. National Park Service, Fort Collins, Colorado.

IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0.1. Armonk, NY: IBM Corp

Jennings, S., Brown, N. and Sheil, D., 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. *Forestry*, 72(1), pp.59-74.

Lima, D., Azambuja, B., Camilotti, V. and Cáceres, N., 2010. Small mammal community structure and microhabitat use in the austral boundary of the Atlantic Forest, Brazil. *Zoologia (Curitiba)*, 27(1), pp.99-105.

Maps.google.com. 2022. *Google Maps*. [online] Available at: <https://maps.google.com/> [Accessed 14 March 2022].

Myers, N., Mittermeier, R., Mittermeier, C., da Fonseca, G. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403(6772), pp.853-858.

Olifiers, N., Bianchi, R., Mourão, G. and Gompper, M., 2009. Construction of arboreal nests by brown-nosed coatis, *Nasua nasua* (Carnivora: Procyonidae) in the Brazilian Pantanal. *Zoologia (Curitiba)*, 26(3), pp.571-574.

Pérez-Irineo, G. and Santos-Moreno, A., 2016. Band size, activity pattern and occupancy of the coati *Nasua narica* (Carnivora, Procyonidae) in the Southeastern Mexican rainforest. *Mammalia*, 80(6), pp.1-7.

Pérez-Irineo, G. and Santos-Moreno, A., 2016. Band size, activity pattern and occupancy of the coati *Nasua narica* (Carnivora, Procyonidae) in the Southeastern Mexican rainforest. *Mammalia*, 80(6).

Püttker, T., Pardini, R., Meyer-Lucht, Y. and Sommer, S., 2008. Responses of five small mammal species to micro-scale variations in vegetation structure in secondary Atlantic Forest remnants, Brazil. *BMC Ecology*, 8(1).

Ray, D., Nair, U., Lawton, R., Welch, R. and Pielke, R., 2006. Impact of land use on Costa Rican tropical montane cloud forests: Sensitivity of orographic cloud formation to deforestation in the plains. *Journal of Geophysical Research*, 111.

Romero, A., Timm, R., Gerow, K. and McClearn, D., 2016. Nonvolant mammalian populations in primary and secondary Central American rainforests as revealed by transect surveys. *Journal of Mammalogy*, 97(2), pp.331-346.

Suunto. 2022. *User guides - Get the most of your Suunto product*. [online] Available at: <https://www.suunto.com/en-gb/Support/User-guides/Suunto-PM-5/6386> [Accessed 15 April 2022].

Taylor, J. and White, S. A., 2007. Observations Of Hummingbird Feeding Behavior at Flowers of Heliconia *Beckneri* and *H. Tortuosa* in Southern Costa Rica. *Ornitologia Neotropical*, 18, pp. 133-138.

University of New Hampshire, 2018. CanopyApp (1.0.3) [App]. Retrieved from: https://apps. apple.com/us/app/canopyapp/id926943048.

Valenzuela, D., 1998. Natural history of the White-nosed Coati, *Nasua narica*, in the tropical dry forests of western Mexico. *Revista Mexicana de Mastazoologica* 3: 26-44.