Habitat Selection of Paca (*Cuniculus paca*) within Cloudbridge Nature Reserve – A Pilot Study

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Introduction

Cloud forests are high-elevation tropical forests that rely heavily on moisture from clouds to hydrate themselves. These highland forests are often characterized by lower species diversity but higher endemism (Nicolau 2022). Unfortunately for cloud forest endemic species, these forest types are much rarer than most other types of tropical forest and are particularly vulnerable to the effects of climate change (Nicolau 2022). As with most tropical forests, mammals are vital to seed dispersal in cloud forests (Nicolau 2022). One such important mammalian seed disperser in the cloud forests of Costa Rica is the paca (*Cuniculus paca*), a large rodent that ranges throughout the neotropics and can be found in a wide variety of habitats (Jax et al. 2015).

Pacas feed primarily on fruits, seeds, and nuts, making them important seed dispersers for a variety of plant species (Jax et al. 2015) (Alvarado-Hernández 2011). According to a study referenced by Jax et al. (2015), pacas avoid competition with their smaller relatives, agoutis, by specializing more in fruits while agoutis specialize more in seeds, though both rodents compete with other species such as peccaries. Paca feed on a wide variety of fruits and the seeds within (Alvarado-Hernández 2011), including cedro macho seeds, avocado, guava (Wainright 2007, p. 225), acorns (García-Hernández et al. 2025), palms (Jax et al. 2015), *Brossimum utile*, monkey apple, figs, passionfruits, mango and cacao (Beck-King et al. 1999). Wainright (2007, p.224-227), Jax et al. (2015), and Beck-King et al. (1999) noted that paca will browse on leaves, flowers, and tree seedlings when fruits and seeds are scarce.

Pacas are also important prey items for many different animals such as jaguar, puma, ocelot, and tayra (Figueroa-de-León et al. 2017). While listed as Least Concern by the IUCN (Emmons, 2016), not considered a conservation priority by many governments, and common throughout much of their range, pacas face threats from overhunting and habitat loss (Jax et al. 2015). Indeed, overhunting for their high value bushmeat has resulted in paca being extirpated from parts of their former range where they were once very common (Jax et al. 2015).

Pacas generally live in monogamous pairs that hold territories of approximately three hectares, though males and females usually sleep and forage separately (Wainright 2007, p.224-227). According to Beck-King et al. (1999), pacas do not exclude other pacas from their territories, meaning that their home ranges often overlap. Jax et al. (2015) found that paca preferred areas with higher tree-density and greater distances from the main road through their study area in Guatopo National Park, Venezuela. While they did not see a strong correlation between paca habitat selection and distance from water as they had expected, Jax et al. (2015) surmised that this may be the result of the abundance of bodies of water throughout the park, so there were no areas with too great a distance from water to affect paca preference. According to Sánchez-Reyes et al. (2023), paca tolerate areas ranging from low to medium human disturbance. Human-disturbed areas that paca inhabit tend to be areas with low human population density such as crop pastures.

Objectives

Primary Objective

The primary objective of this study is to determine the habitat preferences of the pacas within Cloudbridge Nature Reserve both to inform any future management decisions and to help future paca research by providing information on ideal habitat for camera trapping.

Specific objectives

1) Determine how vegetation characteristics – specifically tree density, undergrowth density, canopy cover, and forest growth stage – affect paca distribution.

2) Understand how the presence of other species, particularly pacas' predators and humans, affect paca distribution.
3) Determine how elevation affects paca distribution.

Methodology & Data Analysis

Camera Trapping

This study used a combination of data from the twelve active camera traps set up across the reserve (see **Figure 1.1** and **1.2** for a map of the current camera trap locations), as well as historical data from the camera trap locations corresponding to or very near to the active camera traps. Historical traps considered close enough to have their data incorporated into a current trap's dataset are within 100m of elevation of the active trap, on the same trail, and in the same forest type as the current trap. Horizontal distance was not as strict a criteria for merging a historical trap's data with an active trap's data, provided the historical trap was in the general vicinity of the current trap and met the other criteria.

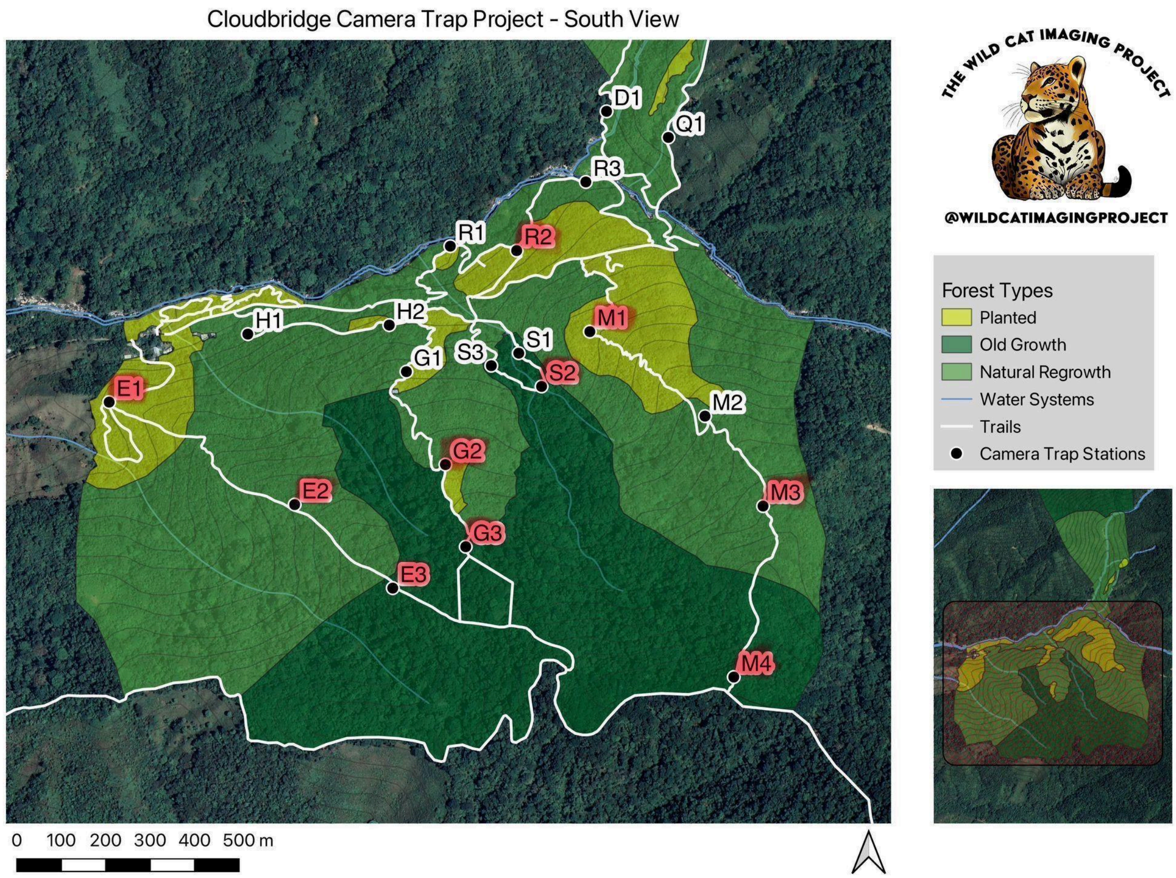

Figure 1.1: Map of current camera trap locations. Sites highlighted in red were active at the beginning of the project's data collection period.

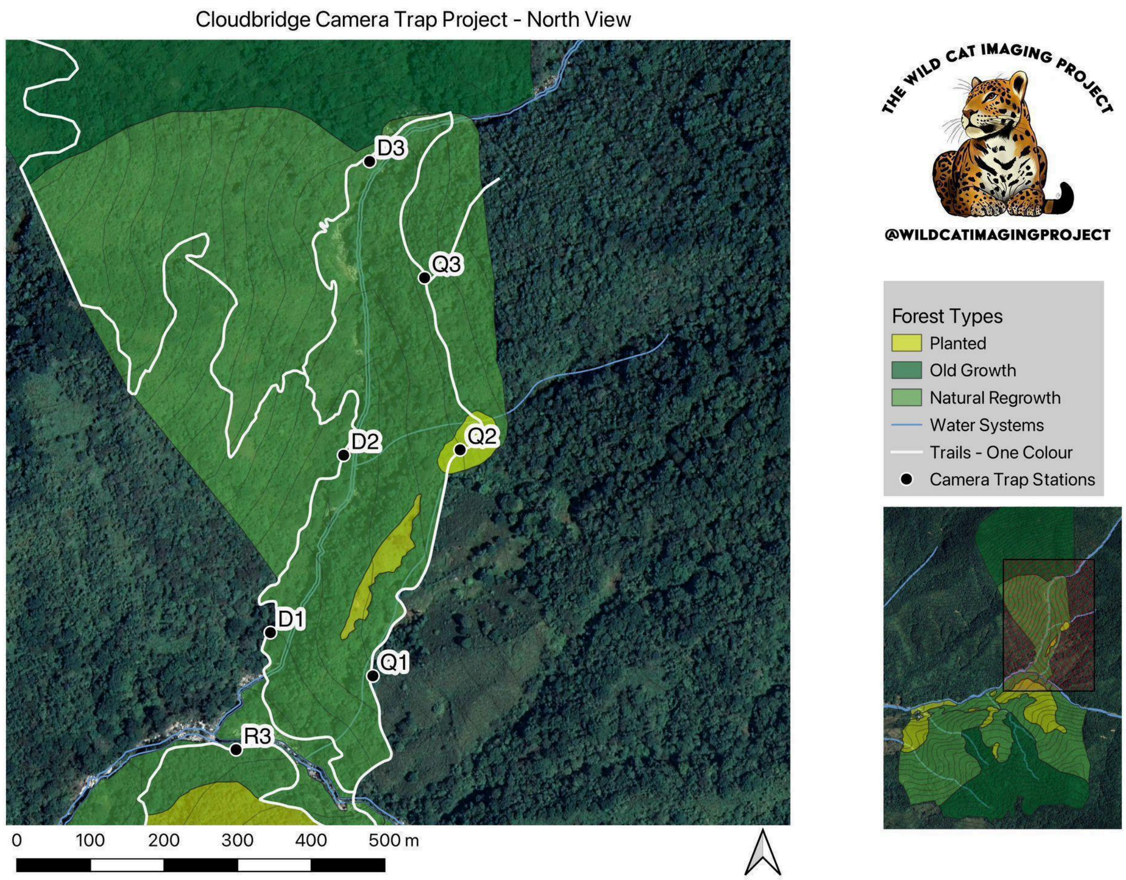

Figure 1.2: Map of current camera trap locations. Only D2 and Q2 were active when data collection for the study began, and the camera at D2 was moved to D1 early during the study.

Detection Frequency

Paca, human, and predator detection frequency were measured by dividing the number of captures by the approximate number of years the camera was active using the following formula: Detection Frequency = (Paca Detections) / [(Total Days Active) / (365 Days per Year)]. Total Days Active was calculated by determining the number of days each camera was active by finding the number of days between the first and last entry for a given camera on each datasheet, then finding the sum of these values. This method of determining detection frequency was a heavily-modified version of the detections-per-time method used in Jax et al. (2015). Because of the limited sample size, changes in the camera trapping project over the years, and the infrequency of paca detections on the cameras, years were used instead of days to provide more intuitive, readable, and easier-to-work-with values. For example, a camera that had one paca detection over 73 days would have a much more digestible detection frequency value if the detection frequency were 5 paca per year (1 paca detection / 0.2 years) instead of 0.01369863 paca per day (1 paca detection / 73 days). Human detections were not recorded prior to 2024, and some of the cameras were placed off-trail, so the total years used to calculate human detection frequencies did not include the number of days the camera was active prior to 2024 or when the camera was located off-trail. Species considered predators of paca for this study were: puma, ocelot, jaguar, jaguarundi, coyote, and tayra.

Habitat Surveys

A DBH survey was conducted at each camera trap location to measure tree density. Surveys were conducted along 25m of trail, surveying up to two meters off trail on both sides as the terrain allowed. During each survey, the percentage canopy cover and the elevation were measured using the iOS application "Tree Density", and a visual estimate of the percentage undergrowth cover was taken. Undergrowth included all non-tree plants that paca or similarly-sized animals could use to hide. This included knee-high to waist-high vegetation, non-trees with space in which to hide, and tall non-tree plants such as bamboo. The percentage was estimated based on the amount of ground covered and the degree to which they obstructed off-trail visibility.

Data Analysis

Using Microsoft Excel, numerical data was visualized using scatterplots, and categorical data was visualized in box-and-whisker plots. To determine statistical significance, p values were calculated using Microsoft Excel's Analysis Toolpak's Regression tool for the numerical data and then compared to an alpha value of 0.05, while the statistical significance of the categorical data was tested by observing overlap in the box-and-whisker plots.

Results

Tree Density

The data in **Figure 2** show a negative correlation between paca detection frequency and tree density. However, the p-value of 0.36 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong positive correlation with tree density is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and tree density.

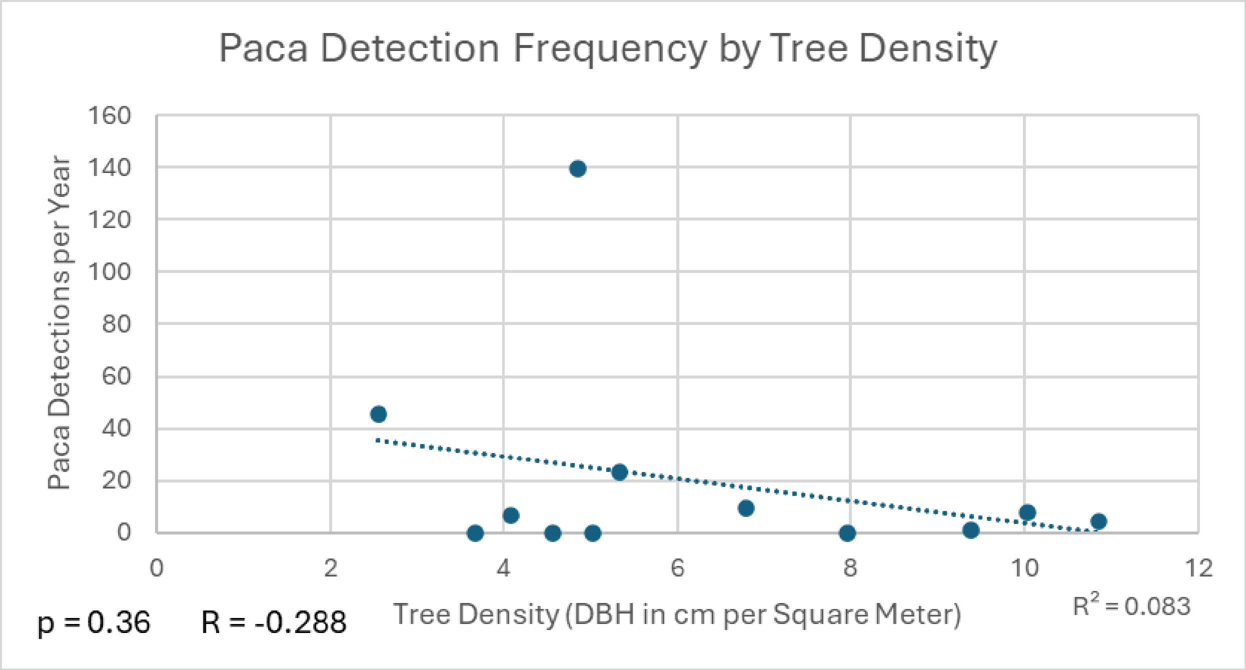

Figure 2: Paca Detection Frequency as a function of Tree Density

Canopy Cover

The data in **Figure 3** show a positive correlation between paca detection frequency and canopy cover. However, the p-value of 0.24 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong positive correlation with canopy cover is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and canopy cover.

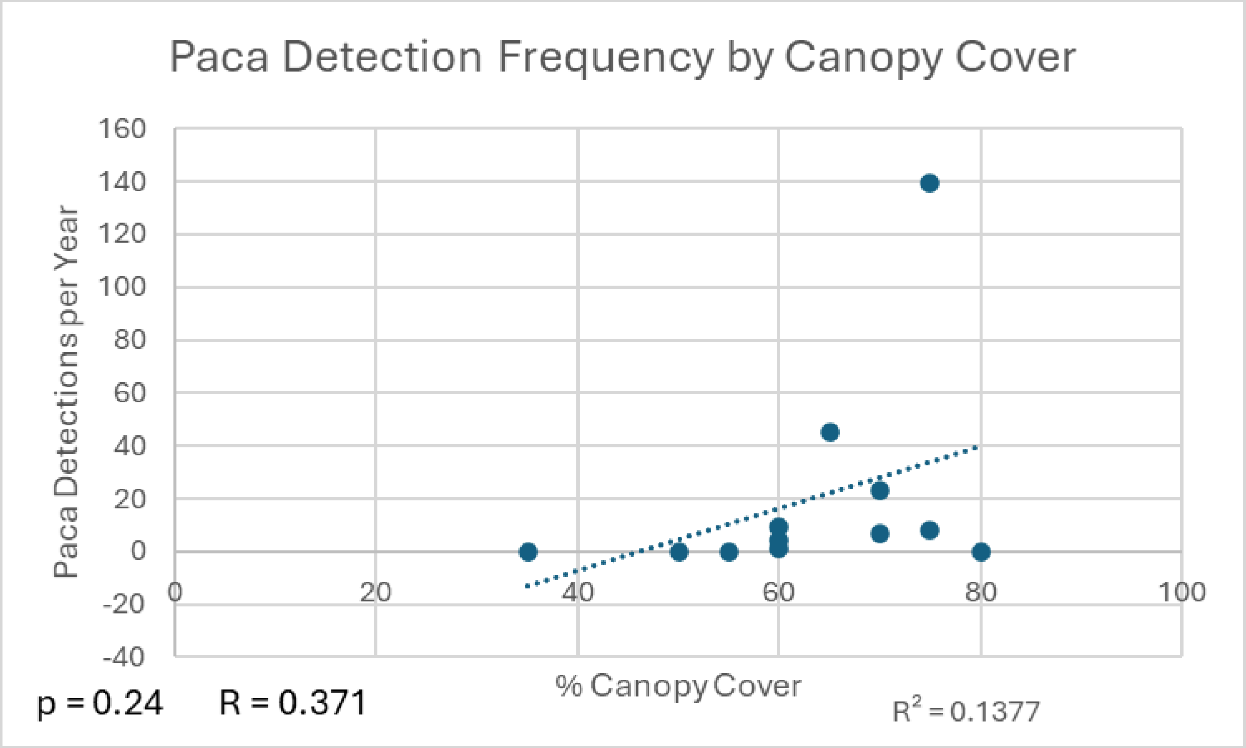

Figure 3: Paca Detection Frequency as a function of Canopy Cover Percentage

Elevation

The data in **Figure 4** show a negative correlation between paca detection frequency and elevation. However, the p-value of 0.18 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong positive or negative correlation with elevation is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and elevation.

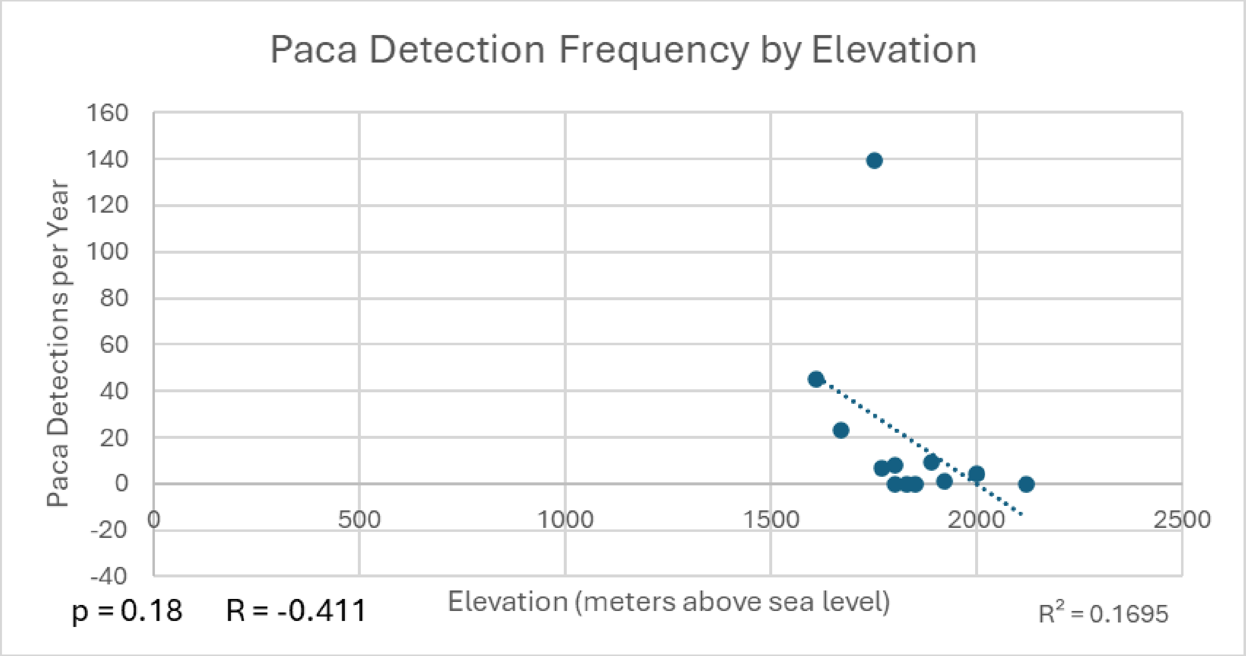

Figure 4: Paca Detection Frequency as a function of Elevation

Human Detection Frequency

The data in **Figure 5** show a negative correlation between paca detection frequency and human detection frequency. However, the p-value of 0.26 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong negative correlation with human detection frequency is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and human detection frequency.

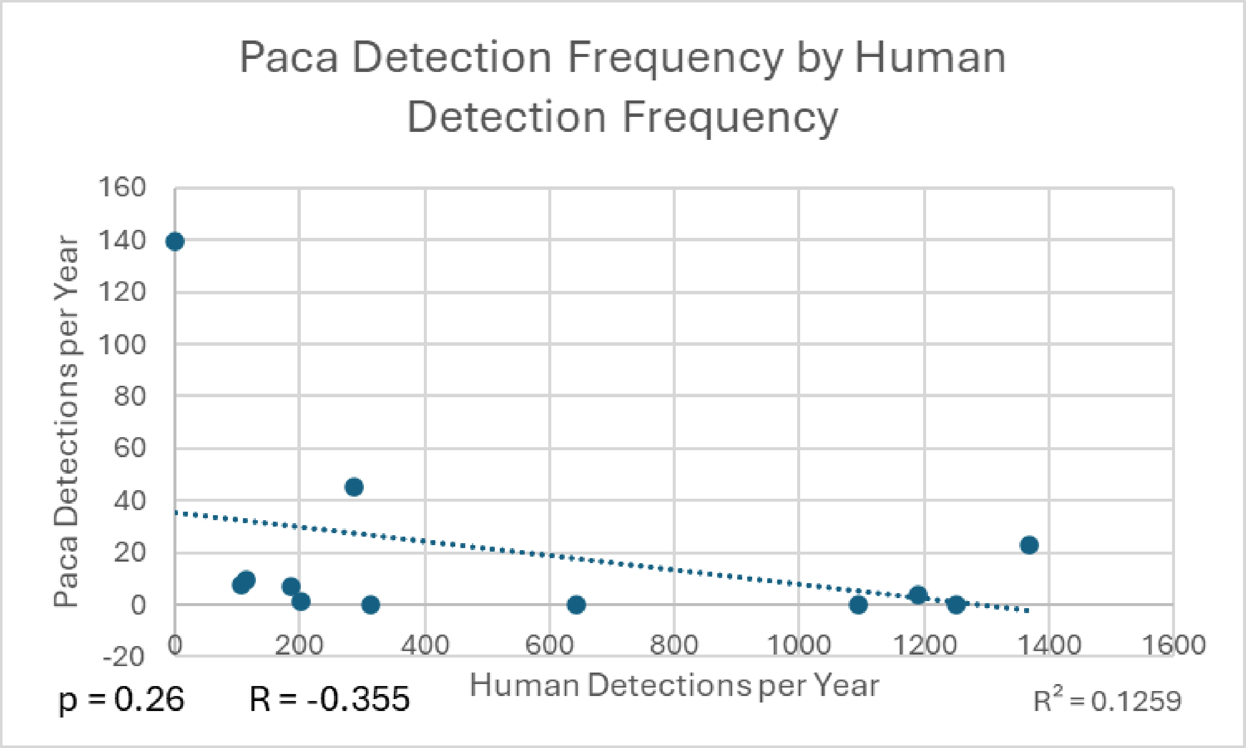

Figure 5: Paca Detection Frequency as a function of Human Detection Frequency

Predator Detection Frequency

The data in **Figure 6** show a slight positive correlation between paca detection frequency and predator detection frequency. However, the p-value of 0.91 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong negative correlation with predator detection frequency is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and predator detection frequency.

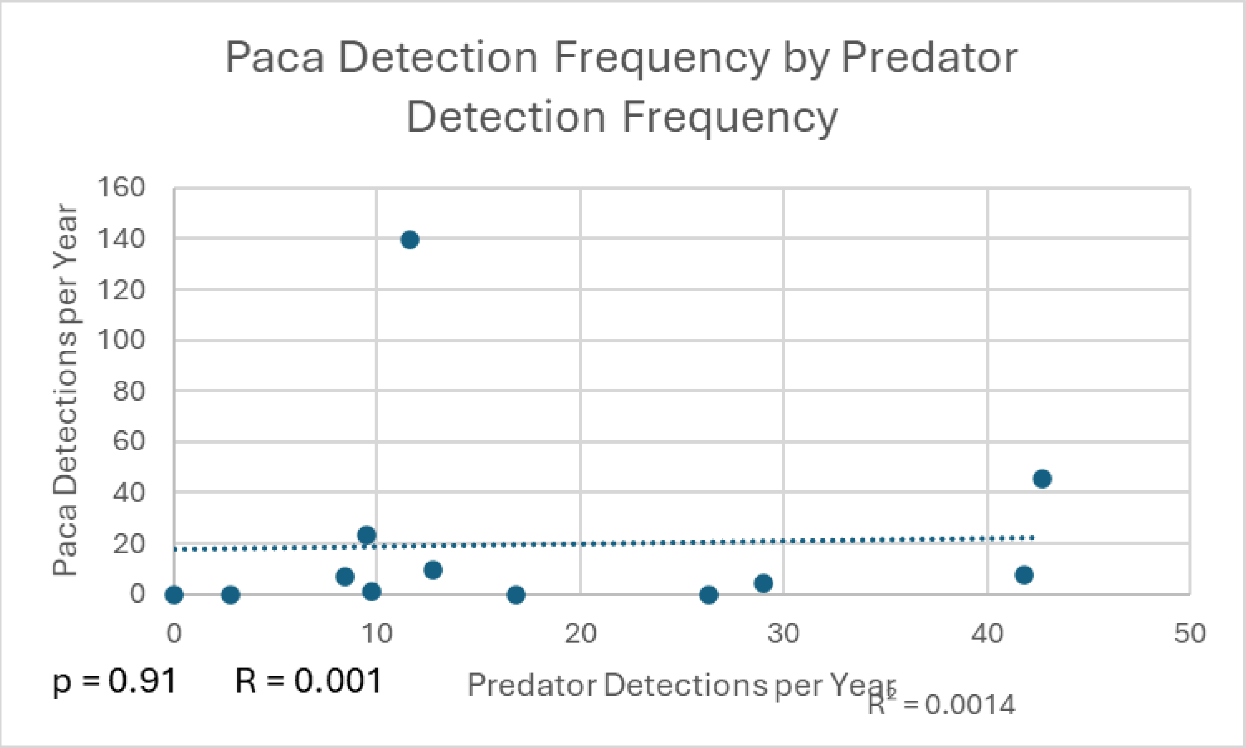

Figure 6: Paca Detection Frequency as a function of Predator Detection Frequency

Undergrowth Density

The data in **Figure 7** show a positive correlation between paca detection frequency and undergrowth density. However, the p-value of 0.28 is greater than the alpha value of 0.05, meaning that the data are not statistically significant. The alternative hypothesis predicting that paca detection frequency would show a strong positive correlation with undergrowth density is rejected in favor of the null hypothesis predicting that there would be no correlation between paca detection frequency and undergrowth density.

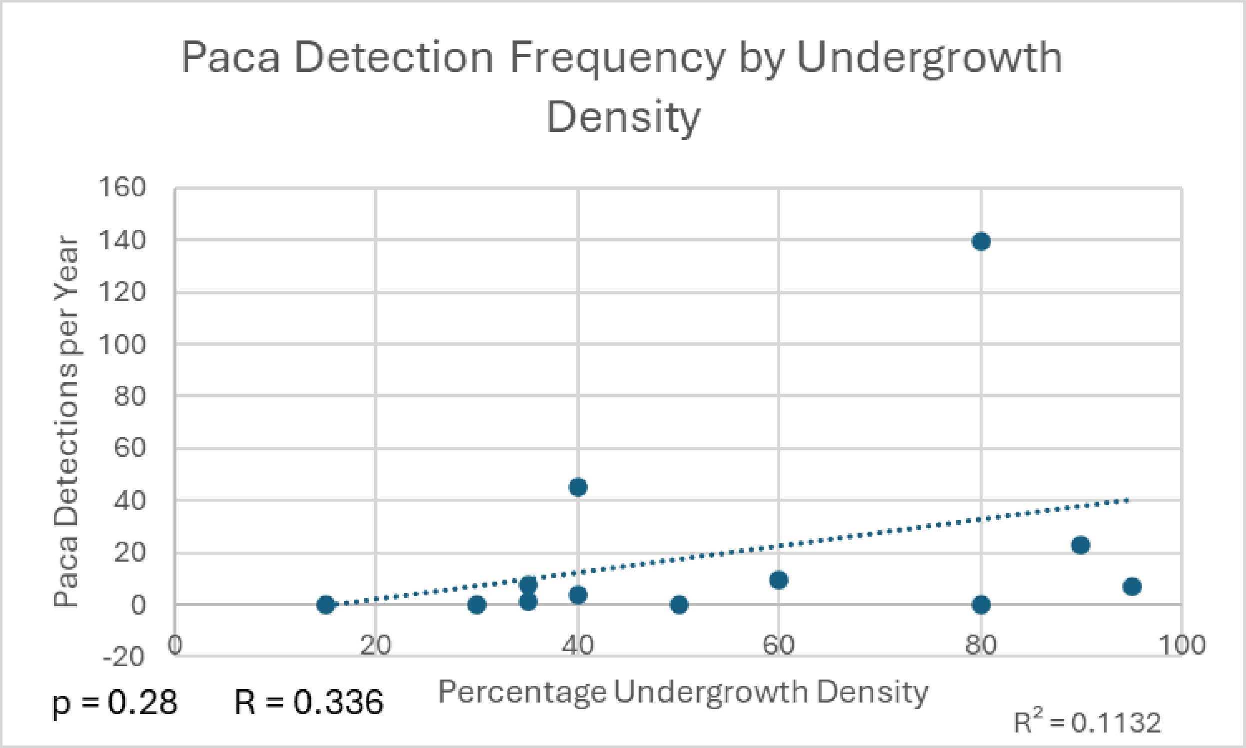

Figure 7: Paca Detection Frequency as a function of Undergrowth Density

Forest Growth Stage

The data in **Figure 8** show that pacas were most frequently detected in natural regrowth forest and least frequently detected in old growth forest. However, the error bars of all three categories heavily overlap, meaning that the differences in paca detection frequency across the three forest growth stages are not statistically significant. The alternative hypothesis predicting that paca detection frequency would differ between the three forest growth stages is rejected in favor of the null hypothesis predicting that there would be no significant difference in paca detection frequency between the three forest growth stages.

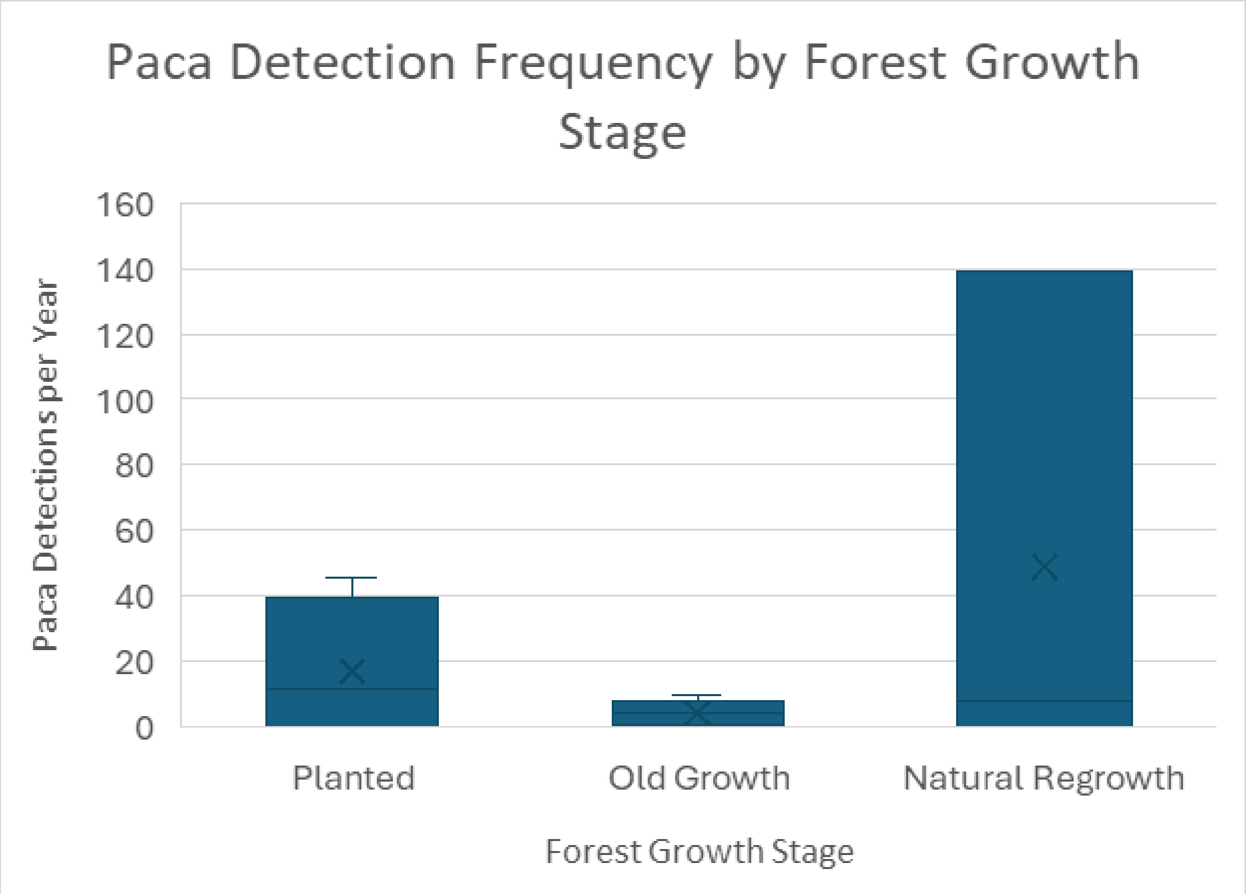

Figure 8: Distribution of Paca Detection Frequencies in different Forest Growth Stages

Discussion

Tree Density

Paca detection frequency shows a negative correlation with tree density (see **Figure 2**), contradicting the findings of studies like Jax et al. (2015) which found that pacas prefer more densely-vegetated habitats. However, this may simply be a result of confounding variables, the limited data, and the many changes the camera trapping project has undergone over time resulting in statistically insignificant data.

Canopy Cover

Paca detection frequency shows a positive correlation with canopy cover (see **Figure 3**), aligning with the findings of studies like Jax et al. (2015) which found that pacas prefer more densely-vegetated habitats. Interestingly, this result seemingly contradicts the result shown in **Figure 2** which shows a negative correlation between paca detection frequency and tree density, though neither result is statistically significant. Furthermore, different trees grow in different ways and high tree density does not always equate to high canopy cover, which depends upon how the canopy grows rather than how the trunks grow. The statistical insignificance of the data may also be a result of the limited data and the many changes the camera trapping project has undergone over time.

Elevation

Paca detection frequency shows a somewhat strong negative correlation with elevation (see **Figure 4**) - the strongest correlation with paca detection frequency of any variable studied. The limited research on highland populations of *Cuniculus paca* or the species' elevational preferences make it difficult to determine whether this result should be expected or unexpected. While Wainright (2007, p.224-227) states that paca may be found anywhere between sea level and 3000m above sea level, there is not a clear indication of any particular elevational preferences within this range, and all of the sites surveyed were within this range of elevations. While this study was being conducted, there was only one in-person paca sighting within the reserve and its immediate surroundings. On April 15th, another research intern encountered a lone paca at the entrance to Chirripó National Park, which is near site M4 and at a slightly higher elevation. Interestingly, no pacas were ever detected on camera M4. The limited range of elevations studied, the only in-person paca sighting on the reserve during the study being higher than any of the study sites, and the lack of literature on pacas' habits in highland habitats or their overall elevation preferences make it unclear whether this finding is entirely the result of the limited sample size or if paca detection frequency does rapidly decrease as elevation increases.

Human Detection Frequency

Paca detection frequency shows a negative correlation with human detection frequency (see **Figure 5**). This result aligns with the findings of studies like Jax et al. (2015), which found that pacas preferred areas in the national park further away from the main roads, and Sánchez-Reyes et al. (2023), which found that pacas prefer areas with low to medium human disturbance, and prefer disturbed habitats with low human population density like crop pastures where they are less likely to encounter humans. While this result is mostly expected, Cloudbridge's and Chirripo's trails do not have as high human traffic as areas such as crop pastures. Furthermore, paca are primarily nocturnal and tend to stay hidden. Therefore it is unclear whether the statistical insignificance of the data is primarily a result of limited data or whether pacas' nocturnal habits and stealthy nature make them less likely to be detected or encountered.

Predator Detection Frequency

There was almost no correlation between paca detection frequency and predator detection frequency (see **Figure 6**). The statistical insignificance of this result is not at all unexpected. Figueroa-de-León et al. (2017) found no correlation between the relative abundance of pacas and the relative abundance of predators, instead finding that the most important factor in relative abundance of pacas was the availability of cavities for hiding and raising young. Paca tend to stay within their territories and flee from predators by hiding in their cavities. The very minor positive correlation between paca detection frequency and predator detection frequency may be explained by predators seeking out areas with more prey items. Additionally, some paca predators like big cats have vast home ranges and roam great distances, making it difficult for pacas to establish their territory in a region with few predators.

Undergrowth Density

Paca detection frequency shows a positive correlation with undergrowth density (see **Figure 7**). This result aligns with the findings of studies like Jax et al. (2015) which found that pacas prefer more densely-vegetated habitats. Much like the data shown in **Figure 3**, this result seemingly contradicts the result shown in **Figure 2** which shows a negative correlation between paca detection frequency and tree density, though neither result is statistically significant. Moreover, tree density and undergrowth density are not always strongly correlated, possibly even less so than tree density and canopy cover. The statistical insignificance of the data may be a result of the limited data and the many changes the camera trapping project has undergone over time, though the result is still expected. Additionally, higher undergrowth density provides paca with more opportunities to avoid detection by cameras, which may have contributed to the lower-than-expected detection frequencies.

Forest Growth Stage

Paca detection frequency is lowest in old-growth forest, slightly higher in planted forest, and by far the highest in natural regrowth forest (see **Figure 8**). Much like the data in **Figure 2**, this result contradicts the findings of studies like Jax et al. (2015) which found that pacas prefer more densely-vegetated habitats. However, both of these results are statistically insignificant, and both may have been confounded by the fact that denser forest is easier to hide in, and may allow paca to escape detection more easily. It is also possible that natural regrowth forest provides pacas with satisfactorily-dense habitat without being so dense that they rarely come into the camera's view. Additionally, the history of the site as farmland has resulted in most of the old-growth forest remaining on steeper, more uneven, and higher-elevation terrain where farming was more difficult, while the lower and flatter areas saw more development. This resulted in the introduction of confounding variables, particularly elevation, into the forest growth stage results. Furthermore, the cameras themselves were not distributed evenly among forests of different growth stages, with five cameras in old-growth forest, four cameras in natural-regrowth forest, and only three cameras in planted forest. Moreover, paca detection frequency shows a positive correlation with both undergrowth density (see **Figure 7**) and canopy cover (see **Figure 3**), which aligns with the findings of Jax et al. (2015).

Reflection and Limitations

Reason for Topic Choice

While there is much research on paca, most studies focus on paca in lowland habitats, leaving a knowledge gap regarding paca habitat preference in montane habitats. This pilot study is intended as a proof-of-concept for a more thorough study on paca habitat preference in foothill and highland habitats to address this gap in knowledge.

Limitations – experience and vegetation surveys

This study ran into many difficulties during the planning and data collection phases. Determining the habitat survey methodology was time consuming, because the methodology required repeated adjustments to work within the limitations of the available field equipment, terrain, seasonal, and weather conditions. For example, the vegetation surveys were intended to involve identifying all paca food plant species, but the combination of the seasonality of plants fruiting, the luck involved in finding the fruits and seeds of all the viable food species at each site, and the difficulty of identifying the species based only on the seeds or fruits – which were often partially decayed or eaten – without seeing their plant of origin, led to the food plants survey being eliminated.

Limitations – camera trap movement and availability

Further problems arose due to camera availability and changes in camera trap placement. Firstly, many cameras stopped working, leading to less data collection overall. Although there were enough functioning cameras to collect sufficient data on more common and braver species like white-nosed coati (*Nasua narica*), collared peccary (*Pecari tajacu*), and tayra (*Eira barbara*), the limited camera traps were insufficient in number, placement, and duration to collect adequate data on more cryptic mammals and gamebirds such as tinamous (Tinamidae spp.), Central-American agouti (*Dasyprocta punctata*), and paca. Further exacerbating this problem was the lack of off-trail cameras. While Cloudbridge has used off-trail cameras in the past, none were active during the study. Moving cameras off-trail was not an option, as multiple projects with different goals shared the same set of cameras and moving them might interfere with other projects. The limited number of active cameras resulted in only twelve sites being surveyed for all camera trapping studies.

The lack of off-trail cameras also resulted in fewer data points for sites with very low human traffic. The changes to the camera trap locations also caused confusion, as some historical trap locations remained as they were, while others were moved, discontinued, or renamed. For example, while the historic M1 is the same site as the current M1, the historical E1 is now called E2 due to a new camera being introduced lower on the trail (see **Figures 1.1** and **1.2** for maps of the current camera trapping sites). Furthermore, the historic E0 was on the Jilguero Loop, whereas the current E1 was originally placed before being moved back to the main trail to its current location. This means that historic E0 and loop E1 must be treated as the same location, and as a separate location from the current E1. While many of the renamed camera traps were either in the same location as a historical trap or relocated a short distance within the same habitat type, there was no record of which historical and current traps corresponded to one another, meaning that each historical location had to be located by GPS and compared to the current camera trap location map. At the time of the study, no comprehensive map of the historical camera trap locations existed; rather, the only record was a list of the historical camera trap sites and their GPS coordinates. Further complicating things, the GPS coordinates of the historical sites are listed in DMS, while the coordinates of the active sites are listed in decimal degrees, meaning some sites' coordinates had to be converted before they could be compared.

Limitations – historical data

While the historical data includes data from off-trail cameras, it was inconsistent with the current methodology and had its own internal inconsistencies. Firstly, different cameras were deployed at different times and were active for vastly different periods of time, resulting in differences in sample size. Secondly, the project did not collect data on human detections until 2024, making it more difficult to assess human detection frequency on each trail. Thirdly, many of the 2025 cameras had no historical counterparts, and even some cameras with historical counterparts had little historical data. Lastly, two of the nearest historical cameras incorporated into the datasets of the current cameras were off-trail, while their current counterparts were placed on the trail.

Limitations – terrain and habitat surveys

While fewer habitat surveys were conducted overall as a result of the merging of historical and current data, the terrain at many camera trap locations made it difficult to consistently survey a 10x10m transect. In some cases, surveying two 5x10m transects on either side of the trail was safe and simple, but on other trails, only a portion of the trail was safe enough to survey resulting in a single 5x20m transect. Sometimes the area surrounding the camera trap was simply too steep to safely survey DBH transects. In order to maintain consistency and safely survey all sites, the methodology was modified to survey two 25x2m transects on either side of the trail. All of these necessary revisions to the habitat survey methodology consumed time that would have been available for surveys.

Cloudbridge's history as a nature reserve built on reforested farmland has resulted in a fairly consistent elevation gradient of forest types. Planted forest is generally at lower elevations, natural regrowth forest is most common at middle elevations, and the majority of old-growth forest on the reserve is at the higher elevations. This elevational gradient – combined with the varying degrees of correlation between forest type, tree density, undergrowth density, and canopy cover – may have led to several variables confounding one another.

Conclusion

Potential changes

There are several changes that could have improved this study. Expanding the study's duration and area – preferably for one or more years and by including Talamanca Reserve and the general San Gerardo de Rivas area respectively – would help mitigate the risk of variables confounding each other in addition to providing a much larger sample size. Using a combination of on-trail and off-trail cameras, possibly baited with scent-lures similarly to Jax et al. (2015), would provide more data overall and assist in isolating human detection frequency as a variable from other habitat characteristics. Larger vegetation survey transects extending further off-trail would more accurately represent the tree density at each site, and multiple food-plant surveys each year would allow the positive identification of the food-bearing plants at each site regardless of weather and fruiting season.

Future Research

The existing scientific literature on *Cuniculus paca* focuses almost exclusively on lowland populations. Studies on if and how pacas' behavior and diet change with habitat are scarce. Future research focusing on dietary differences between lowland and highland populations of *Cuniculus paca* would also be helpful for building a more extensive knowledge base for future paca research.

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Works Cited

Alvarado-Hernández, A. M. (2011). *Caracterización Floristica de los hábitats utilizado por el tepezcuintle Cuniculus paca, (LINNEO, 1766; Rodentia: Cuniculidae), en el piso basal del parque nacional Carara, Costa Rica*. https://repositoriotec.tec.ac.cr/handle/2238/2952

Beck-King, H., von Helversen, O., & Beck-King, R. (1999). Home Range, Population Density, and Food Resources of Agouti paca (Rodentia: Agoutidae) in Costa Rica: A Study Using Alternative Methods. *Biotropica*, *31*(4), 675–685. https://www.jstor.org/stable/2663909

Emmons, L. (2016). IUCN Red List of Threatened Species: Cuniculus paca. *IUCN Red List of Threatened Species*. https://www.iucnredlist.org/en

Figueroa-de-León, A., Naranjo, E. J., Perales, H., Santos-Moreno, A., Lorenzo, C., (2017). Abundance, density and habitat use of lowland paca (Cuniculus paca, Rodentia: Cuniculidae) in the Lacandon Rainforest, Chiapas, Mexico. *Therya*, *8*(3), 199–208. https://doi.org/10.12933/therya-17-460

García-Hernández, M. de los Á., López-Barrera, F., Sosa, V. J., Pérez-Ramos, I. M., & Perea, R. (2025). Acorn dispersal effectiveness after 27 years of passive and active restoration in a Neotropical cloud forest. *Science of The Total Environment*, *966*, 178770. https://doi.org/10.1016/j.scitotenv.2025.178770

Jax, E., Marín, S., Rodríguez-Ferraro, A., & Isasi-Catalá, E. (2015). Habitat use and relative abundance of the Spotted Paca Cuniculus paca (Linnaeus, 1766) (Rodentia: Cuniculidae) and the Red-rumped Agouti Dasyprocta leporina (Linnaeus, 1758) (Rodentia: Dasyproctidae) in Guatopo National Park, Venezuela. *Journal of Threatened Taxa*, *7*(1), Article 1. https://doi.org/10.11609/JoTT.o3915.6739-49

Nicolau, P. I. M. (2022). *Microhabitat Preference of the White-nosed Coati (Nasua narica) in a Costa Rican Cloud Forest*.

Sánchez-Reyes, M., Chiappa-Carrara, X., Vázquez-Domínguez, E., Yáñez-Arenas, C., Falconi, M., Osorio-Olvera, L., Contreras-Díaz, R. G., Sánchez-Reyes, M., Chiappa-Carrara, X., Vázquez-Domínguez, E., Yáñez-Arenas, C., Falconi, M., Osorio-Olvera, L., & Contreras-Díaz, R. G. (2023). Human footprint effects on the distribution of the spotted lowland paca (Cuniculus paca). *Therya*, *14*(1), 75–83. https://doi.org/10.12933/therya-23-2237

Wainwright, M. (2007). *The Mammals of Costa Rica: A Natural History and Field Guide*. Comstock.