Distribution and habitat use of the cougar (*Puma concolor*) in Cloudbridge Nature Reserve

Research Internship Report

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Abstract

Understanding the distribution and habitat preferences of large carnivores is essential for biodiversity conservation in tropical ecosystems. This study investigates the spatial distribution and habitat use of the puma (*Puma concolor*) within Cloudbridge Nature Reserve, a cloud forest in the Talamanca Mountains of Costa Rica. Using camera traps placed throughout the reserve, puma presence was monitored and analysed. The study evaluated which environmental factors (forest type, elevation, seasonal variation, prey abundance, human activity, canopy cover, and forest density) were the best predictors of puma abundance. Results showed significant variation in puma observations across forest types and elevation bands, with the highest activity in natural regrowth forests and mid-elevation zones. Prey abundance was positively correlated with puma presence, particularly for collared peccaries and white-nosed coatis. No significant relationship was found between puma presence and human activity, canopy cover, or forest density, though data limitations and trail-based sampling may have influenced results. Recommendations for improving future monitoring include better camera maintenance, standardized deployment, and expanded off-trail sampling. This study contributes to a better ecological understanding of pumas in tropical montane forests and supports ongoing conservation efforts in the region.

Contents

Table of figures

Introduction

Background

Costa Rica is well known for its biodiversity. Especially with its forests, which serve as vital ecosystems for a rich variety of species. The various forest types present in the country collectively establish a wide array of habitats, supporting high species richness among both flora and fauna. One of these forest types is the tropical cloud forests (TCFs). TCFs are characterized by constant, frequent or seasonal cloud cover at the forest canopy, with most of them located in mountain ranges at high elevations (Ray et al., 2006). The moisture from clouds and mist is an essential factor in creating the conditions necessary for plants and animals to thrive. Especially during the dry season, horizontal precipitation plays a crucial role in the area's hydrology, by maintaining the ecosystem's water balance (Ray et al., 2006).

TCFs are among the most diverse terrestrial ecosystems in the world, with a high number of unique and endemic species (Karger et al., 2021). In 2001, cloud forests covered just 0.4% of the Earth's land surface but were home to around 3,700 species of mammals, birds, amphibians, and tree ferns, representing about 15% of the global diversity in those groups. Remarkably, half of these species were found exclusively in cloud forests (Karger et al., 2021). This emphasizes the importance of tropical cloud forests in providing the precise conditions for species to thrive. Unfortunately TCFs are threatened by direct human activities, such as deforestation, and climate change. Between 2001 and 2018, approximately 2.4% of cloud forests were lost globally, with losses exceeding 8% in certain areas, mainly in regions that are easy to access (Karger et al., 2021). In Costa Rica, less than 25% of the original vegetation of the TCFs remains due deforestation and climate change, according to Ray et al. (2006).

This loss of cloud forests also affects the animal species. Terrestrial mammals play a crucial role in tropical forest ecosystems, serving as indicators of ecosystem health and offering valuable services. However, there is a lack of detailed data on how these species are impacted by local, regional, and global threats (Ahumada et al., 2011). Carnivores living in the forests are predators that play a key role in the ecology of the forest, such as population control and resource facilitation (Cepeda–Duque et al., 2021). Carnivores not only influence the population size of their prey, but also facilitate resources for other species, for example by leaving behind carcasses that provide food for scavengers, or by limiting herbivore populations, which allows more space and resources for plants and other animals (Allen et al., 2014). However, there is limited knowledge on their activity patterns and their influence on the behaviour of potential preys in tropical environments (Cepeda–Duque et al., 2021). A better understanding of the ecological role of carnivores in ecosystems such as cloud forests offers insights into their effects on prey population structure and their contribution to resource facilitation (Murphy & Ruth 2009).

The top predators in the cloud forests of Costa Rica are the cougar (Puma concolor) and the jaguar (Panthera onca). The puma was chosen for this study because of its role as a top predator, its adaptability to various environments, and the lack of data on its behaviour and habitat use in cloud forests.

The puma is a large secretive cat and is the most adaptable feline in the Americas as it is found in a variety of different habitats, unlike other cat species. These habitats are cloud forests, tropical jungle, grasslands, and even arid desert regions (Nielsen et al., 2015). The puma has the widest geographic distribution of any terrestrial mammal in the Western Hemisphere, spanning from Canada and the United States through Central and South America all the way to southern Chile (Nielsen et al., 2015).. They are found at elevations ranging from sea level to 5,800 meters (Nielsen et al., 2015). Pumas live in large areas, but are hard to see, and difficult to track. For this reason, there is little information on their population numbers (Murphy et al., 2019). This is the case at Cloudbridge Nature Reserve, a reserve in the Talamanca mountains, where pumas are found but their populations, distribution and habitat use in the forest is very understudied. In this study, the aim was to gain a better understanding of the puma in Cloudbridge Nature Reserve. The research focused on the distribution and habitats of the puma within the reserve, as well as the factors that may influence its distribution and habitat use.

Many factors influence the distribution and habitat use of pumas in the cloud forests. Both abiotic and biotic factors shape where species occur in an ecosystem. Abiotic factors such as temperature, moisture, and elevation are especially important for pumas inhabiting cloud forests (Potts et al., 2020). The high moisture levels support year-round plant growth, contributing to dense vegetation structures—particularly in old-growth forest areas (Gray et al., 2023). Pumas tend to prefer mid- to high-elevation zones, where human disturbances are lower and prey availability is suitable (Laundré & Hernández, 2003).

Biotic factors, such as the presence of other predators, also affect puma abundance. Scognamillo et al. (2003) found a high degree of spatial overlap between jaguars and pumas, likely related to prey distribution. However, the two species show dietary separation: jaguars typically hunt larger prey, while pumas focus on medium-sized animals. Seasonal variation in activity levels may reflect these dietary preferences.

Because it was not possible to examine all potential factors, a number of measurable variables were selected that are relevant to the context of Cloudbridge Nature Reserve.

The type of forest may influence the distribution of the puma, as some forest types are more suitable as habitat than others. In Cloudbridge Nature Reserve, three different forest types are present: old-growth forest, planted forest, and natural regrowth forest. Habitats in old-growth forests differ significantly from those in planted forests. Old-growth forests tend to have a much denser canopy, thicker undergrowth, and larger, more mature trees, creating a more complex and diverse environment (Gray et al., 2023). These features offer a greater variety of shelter, foraging opportunities, and hiding spots for wildlife, providing a more stable and enriched habitat compared to planted forests, which may lack the structural complexity and biodiversity of older, natural ecosystems.

Although pumas are observed at various elevations, elevation may still be a factor influencing their distribution in cloud forests. Old-growth forests are more commonly found at higher elevations than other forest types (Gordillo et al., 2021). As previously mentioned, mammals appear to prefer old-growth forests as habitat. However, there is still a lack of data interpretation regarding local elevation differences in biodiversity within cloud forests and larger mammals (Bevilacqua, 2023).

Seasonal differences could also affect the distribution of pumas, especially given their large home ranges. It is possible that they find the cloud forest more appealing during the rainy season than in the dry season. Seasonal changes can negatively affect mammals, due both to their seasonal breeding behavior and to changing weather conditions that influence resource availability and competition (Batzli, 2001). According to Grigione et al. (2006), the effect of seasons on puma home range varied between study areas.

Prey availability itself is a key factor in puma distribution. Pumas are more frequently present in areas where prey species are detected more often (Coon et al., 2020). The common prey species in cloudforests are collared peccary (*Pecari tajacu*), paca (*Cuniculus paca*), common opossum (*Didelphis marsupialis*), white-nosed coati (*Nasua narica*), common agouti (*Dasyprocta punctata*), Central American agouti (*Dasyprocta punctata*), dice's cottontail (*Sylvilagus dicei*), Baird's tapir (*Tapirus bairdii*), nine-banded armadillo (*Dasypus novemcinctus*), white-tailed deer (*Odocoileus virginianus*), northern tamandua (*Tamandua mexicana*) and white-headed capuchin (*Cebus capucinus*) (Botts et al., 2020).

Additionally, human presence strongly influences puma behavior and abundance. Pumas are considered sensitive to human activity and typically avoid areas with high human disturbance (Logan & Sweanor, 2001).

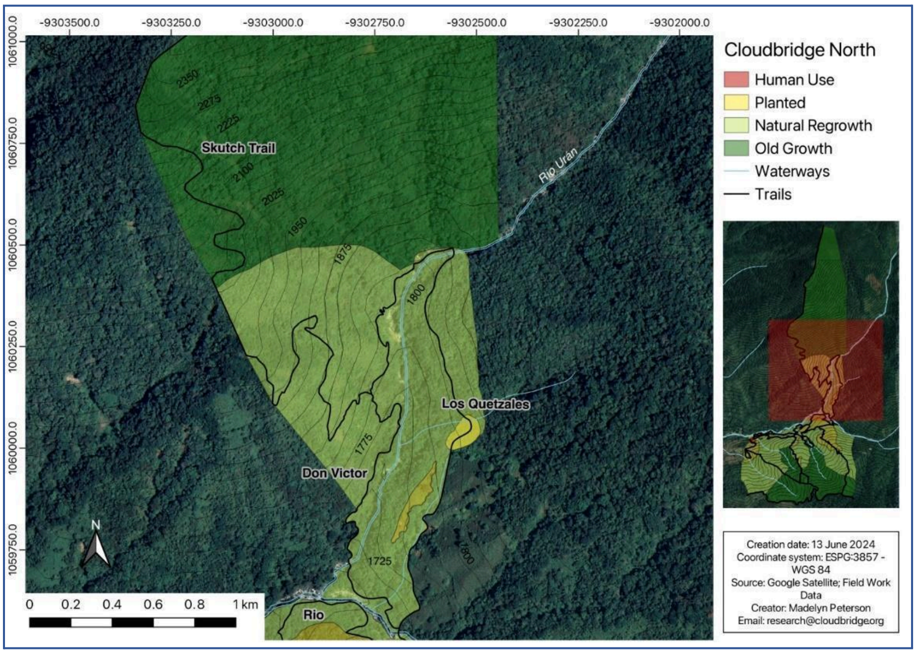
Canopy cover is an important factor as it provides shelter, breeding and nesting spaces, food resources, and helps both predators and prey remain hidden (Spencer et al., 2005). There is limited knowledge regarding the impact of vegetation cover on community and population dynamics. The study by Bevilacqua (2023) shows that canopy cover has a significant influence on mammal populations in Cloudbridge. In general, mammal diversity tends to increase as canopy cover decreases. In contrast, the trend for abundance is less clear: abundance often increases as canopy cover becomes denser (Bevilacqua, 2023). While a reduction in canopy cover has been clearly linked to lower abundance of small mammals, the relationships with larger mammals and overall mammal community structure are less pronounced (Spencer et al., 2005). This may explain why the correlation with canopy cover is not always straightforward, despite the generally positive trend.

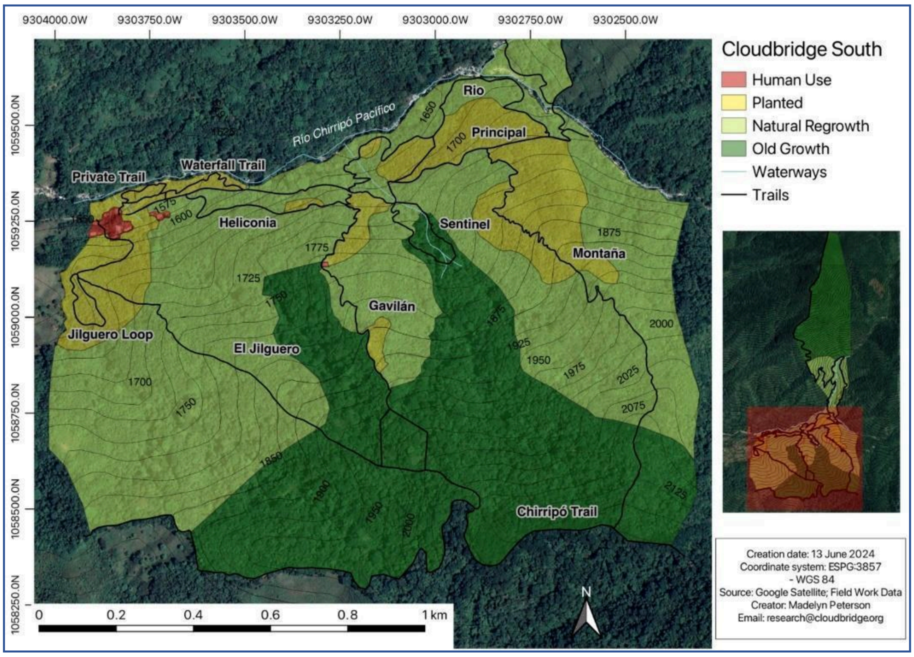
Forest density can also play a role in puma distribution. Pumas prefer cloud forests with dense vegetation and ample cover. The results of the study of Coon et al., 2020 show that pumas primarily occupy forested habitats and do not specifically select areas with high deer density. Instead, they favour environments that support their stalk-and-ambush hunting strategy rather than those with merely higher prey density.

To study the distribution and habitat use of the puma in the Cloudbridge Nature Reserve, camera traps are used. Camera trapping is a common method for analyzing mammal activity. By placing cameras in various locations with different habitats throughout the reserve, observations can be made in different areas. Additionally, environmental factors that may influence puma presence are measured, which will be discussed further in the methodology section.

Area

Located in Costa Rica's Talamanca Mountains, Cloudbridge is a privately managed nature reserve ranging in altitude from 1,550 to 2,600 meters (Cloudbridge Nature Reserve, n.d.). This elevation range places the reserve firmly within the cloud forest ecosystem, characterized by persistent mist and high humidity that support a rich diversity of flora and fauna. Cloud forests are known for their dense vegetation, abundant epiphytes, and unique microclimates, making them critical habitats for many endemic and endangered species (Krasilnikov, 2020). Since 2002, Cloudbridge has expanded from 255 hectares of previously used pasture and farmland, alongside 28 hectares of untouched primary forest, to a total of 700 hectares. The reserve now contains a mosaic of forest types including primary forest, mature forest, naturally regenerated young forest, and planted forest areas (Cloudbridge Nature Reserve, n.d.). Figure 1 presents a map of Cloudbridge North, highlighting the different forest types and the trails, along with elevation contours in meters. Figure 2 shows similar information for the southern section of the reserve. The cloud forest conditions create unique environmental gradients that influence species distribution and ecological processes throughout the reserve.





The old growth forest appears to be located at a higher elevation compared to other forest types (see Figures 1 and 2). This suggests a possible relationship between elevation and forest type. It's likely that the lower parts of the reserve were easier to convert into farmland, leaving the higher, less accessible areas (like the old forest) largely intact.

Aims and objectives

The main aim of this study was to determine the differences in the distribution and habitat use of the puma in Cloudbridge Nature Reserve, as well as the factors that influence them.

The objectives are as follows:

- To investigate the spatial distribution of pumas within Cloudbridge Nature Reserve.
- To analyse the habitat preference of the puma in Cloudbridge Nature Reserve.
- To determine which factors (forest type, elevation, seasonal variation, prey abundance, human abundance, canopy cover, and density) are the best predictors of abundance of the puma.

Methodology

Data Collection

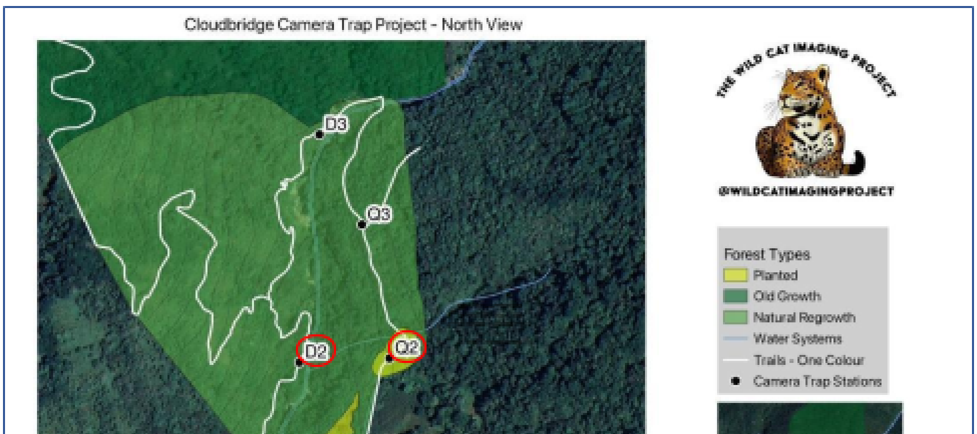
Camera traps

Since the camera trap project at Cloudbridge has been running since 2024, the traps were already installed at various locations throughout the reserve. They were strategically distributed across different forest types and elevations to incorporate these variables into data collection. Ideally, three camera traps were placed in each forest type, totaling 12 cameras. The traps were positioned along various trails within the Cloudbridge Nature Reserve, as shown in Figures 3 and 4. Some trails have more cameras than others. In previous years, a larger number of sites were used for camera placement, but as of 2025, 10 specific locations are actively used for camera traps.

The exact locations of the 10 camera traps that were installed across the reserve as shown with red circles in Figure 3. and Figure 4. The coordinates of each trap are listed below in Table 1.

Table 1. Coordinates of the camera traps

Camera trap	Latitude	Longitude	Trail	Forest type
D2	9.47881° N	83.56771° W	Don Victor	Natural regrowth
Q2	9.47886° N	83.56618° W	Los Quetzales	Planted
E1	9.47074° N	83.57872° W	Jilguero	Planted
E2	9.46867° N	83.57492° W	Jilguero	Natural regrowth
E3	9.46698° N	83.57291° W	Jilguero	Old growth
G2	9.46948° N	83.57183° W	Gavilan	Natural regrowth
G3	9.46800° N	83.57125° W	Gavilan	Old growth
S2	9.47095° N	83.57028° W	Sentinel	Old growth
M3	9.46927° N	83.56533° W	Montaña	Old growth
M4	9.46565° N	83.56593° W	Montaña	Old growth



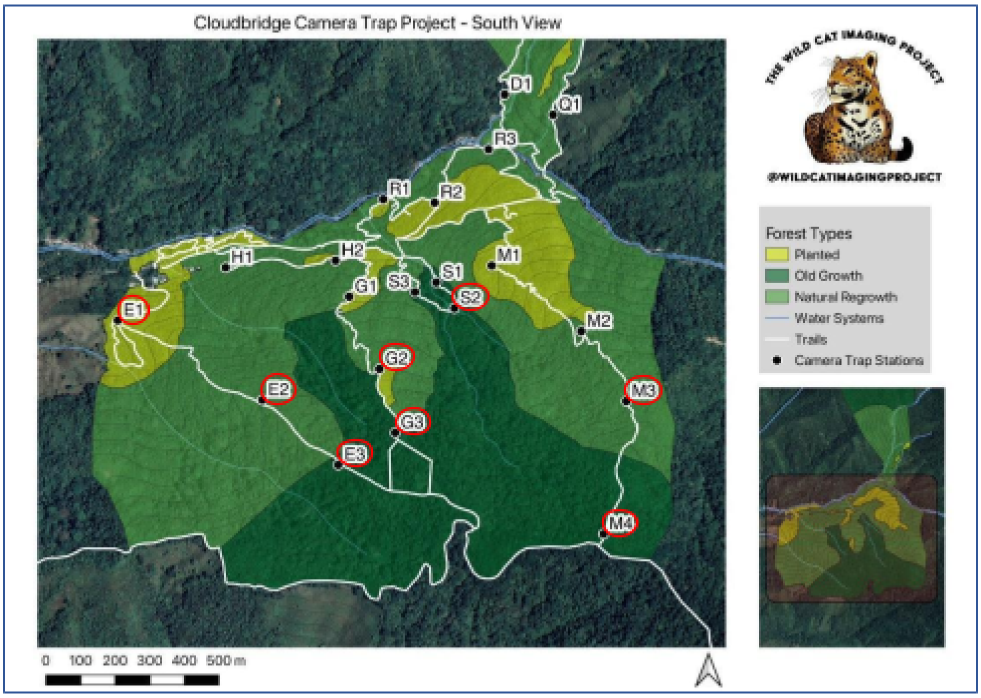


Figure 4. Camera trap locations Cloudbridge South. Cameras still active are circled in red.

All cameras were configured with the same settings: each camera recorded 10-second videos when motion was detected, with sound enabled, and the date and time checked regularly. The cameras used infrared for nighttime recordings and recorded in color during daylight. They were equipped with temperature-sensitive sensors that automatically adjusted to enhance motion detection accuracy (van de Walle, 2024). The cameras in the field recorded continuously and captured all species. Every two weeks, the SD cards and batteries were replaced.

The data was analysed by reviewing all footage collected from the SD cards. The abundance of mammals was determined by counting the number of individual mammals observed on the videos. Mammals appearing in multiple videos on the same camera within 30 seconds were considered the same individual. Although many mammals recorded outside of this time frame were likely the same individuals, they were treated as separate in this study due to the considerable difficulty of identifying individuals in many species.

Because the abundance of other animals, such as puma's preys and humans, could provide valuable context for interpreting puma presence, all other species captured in the camera trap data were also counted. This information was compiled into a comprehensive database.

To evaluate the environmental factors, specific methods were implemented to measure their presence and variation across the Cloudbridge Reserve.

Forest type

The forest type at each camera trap location was determined using Cloudbridge records. The forests were categorized into three types: planted, natural regrowth, and old growth.

Elevation

The elevation differences within Cloudbridge Reserve had already been mapped, as shown in Figures 1 and 2. To obtain more precise data, the elevation at the exact locations of the camera traps was measured using a GPS device.

Seasonal variation

To explore seasonal and temporal patterns in puma activity, the number of individual puma sightings recorded by each camera was counted for each month during the study period. This allowed for comparisons between the dry and rainy seasons. Additionally, the data were analyzed to identify differences in puma activity between day and night, providing insight into how seasonal and daily cycles may influence their behaviour and presence within the reserve.

Prey presence

The puma, as a large feline, primarily prey on other mammals. To explore their relationship with prey species and possibly the effect of prey presence, the camera traps were also used to map the distribution of these prey animals. The video footage from each camera was checked for prey species. The most common species in the Cloudbridge Reserve were the collared peccary (*Pecari tajacu*), Central American agouti (*Dasyprocta punctata*), common opossum (*Didelphis marsupialis*), Dice's cottontail (*Sylvilagus dicei*), paca (*Cuniculus paca*), and white-nosed coati (*Nasua narica*).

Human presence

Human presence was assessed by counting the number of individuals captured on video passing by each camera trap. This included both tourists visiting the reserve and researchers conducting fieldwork.

Canopy cover

This was measured as the percentage of light reaching the phone camera using the CanopyViewer app. Measurements were taken at 7 points along each 50-meter transect: one directly at the camera trap, and three points in both directions along the trail, on both sides of the transect. Data collection took place at the start of the project.

Forest density

To accurately assess forest density at the camera trap locations, the Basal Area Method was employed. This method provides a standardized measure of tree density by calculating the basal area of individual trees within a defined plot. In this study, a 20-meter transect was used, measuring the DBH of all trees taller than 1,3 meter within a 1-meter width on either side of the transect. Given that the trail path itself is also 2 meters wide, the total plot area amounted to $20 \times (2 + 1 + 1) = 100\ m^2$, see Figure 5.

The Basal Area Method involves measuring the trunk diameter of all trees within plot at 1.3 meters height (DBH: Diameter at Breast Height). For each tree, basal area is calculated using the formula: Basal Area = $\pi \times (DBH/2)^2$, where DBH must be in meters for the result to be in square meters (m^2), or the formula can be adjusted if DBH is measured in centimeters (Elledge & Barlow, 2018). The total basal area of the plot is the sum of the basal areas of all trees within the plot. To estimate basal area per hectare, the plot's basal area is multiplied by 100, since one hectare equals 10,000 m^2, allowing comparison with standard values (Elledge & Barlow, 2018).

Data analysis

All collected data from the camera traps were compiled into a structured database, including information on puma sightings, other mammal species (prey), human presence, forest type, elevation, vegetation density, and canopy cover, with date and time also serving as important variables for the analysis. This data was analysed using RStudio.

Statistical comparisons were made to examine relationships between puma presence and all the variables. Temporal patterns were evaluated by comparing puma activity across years and months (dry vs. rainy season). To determine whether there were significant positive or negative correlations between these factors and puma presence, various statistical tests were used. Graphs and summary tables were generated to visualize differences, and patterns in habitat use were interpreted to better understand puma behaviour within the landscape.

It is important to note that for the analysis of the factors forest type, elevation, and seasonal variation, a long-term dataset (2015–2025) was used, consisting of all recorded sightings of wild felids in the Cloudbridge Nature Reserve during this period. These factors are relatively stable over time and are not directly influenced by short-term fluctuations. Therefore, using a larger dataset spanning multiple years adds value and reliability to the analysis.

For the analysis of camera trap locations and comparisons with the variables prey presence, human presence, canopy cover, and forest density, data from the 2024–2025 period was used. These variables are highly time-sensitive and must be recorded simultaneously with puma observations. Only when the data are collected during the same time frame can valid comparisons be made between puma presence and environmental factors.

The different statistical tests used in this study were the chi-square test, the Kruskal-Wallis test, and linear regression (t-test).

The chi-square test was used to assess whether there was a significant association between two categorical variables. It compared the observed frequencies in each category with the frequencies that would have been expected if there had been no relationship between the variables (McDonald, 2014). A significant result indicated that the variables were not independent and that there was likely an underlying association (McDonald, 2014).

The Kruskal-Wallis test was used to determine whether there were statistically significant differences between three or more independent groups. It is a non-parametric method, meaning it does not assume a normal distribution of the data. Instead of comparing means, the test compared the median ranks of the groups(McDonald, 2014). A significant result indicated that at least one group differed significantly from the others (McDonald, 2014).

Linear regression was used to examine the relationship between a continuous dependent variable and one or more independent variables. It estimated how much the dependent variable changed when the independent variable increased by one unit (McDonald, 2014). The t-test within the regression analysis was used to determine whether the relationship between each independent variable and the dependent variable was statistically significant (McDonald, 2014).

For all statistical tests, a p-value less than 0.05 ($p < 0.05$) indicated a statistically significant difference or association. A p-value greater than 0.05 ($p > 0.05$) indicated no statistically significant difference or association.

Results

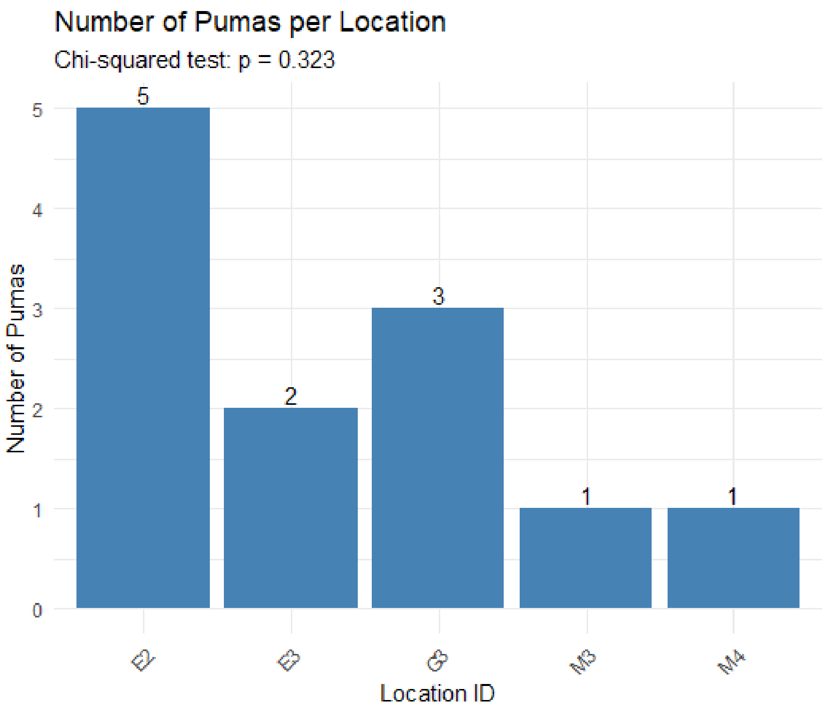
All environmental variables measured in the field in 2025 are summarized in Table 2, with basal area serving as an indicator of forest density. Old-growth forests were generally found at higher elevations compared to the other forest types; however, this difference was not statistically significant (Kruskal-Wallis test, $p = 0.1208$). Similarly, canopy cover was slightly higher on average in old-growth forests than in planted and natural regrowth forests, but no significant differences were detected (Kruskal-Wallis test, $p = 0.727$). Additionally, no significant association was found between forest type and basal area (Kruskal-Wallis test, $p = 0.235$).

Table 2. Factors at the camera trap locations (2025)

	E1	E2	E3	G2	G3	D2	Q2	M3	M4	S2
Forest type	Planted	Natural regrowth	Old growth	Natural regrowth	Old growth	Natural Regrowth	Planted	Old Growth	Old Growth	Old Growth
Elevation (m)	1610	1800	1920	1850	1890	1750	1800	2000	2120	1770
Canopy cover	65%	75%	60%	35%	60%	76.75%	55%	60%	80%	70%
Basal area (m^2/ha)	27.03	158.75	155.63	27.11	137.05	71.44	70.80	255.40	47.28	75.32

Camera locations

Figure 6 displays the puma observations recorded at all camera trap locations during the 2024–2025 monitoring period. Puma detections were recorded at only five of the locations, while no observations were made at E1, G2, D2, Q2, and S2. Among the locations with detections, E2 recorded the highest number of observations (n = 5), followed by G3 (n = 3). Statistical analysis indicated no significant differences in the number of puma observations between the different locations (Chi-squared test, p = 0.323).



Forest type

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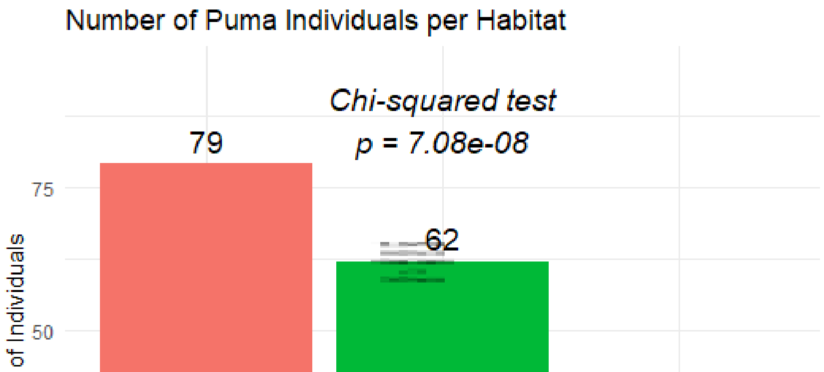


Elevation

The various camera locations were situated at different elevations. These were compared to the number of puma observations from 2015 to 2025. In Figure 8, the density of puma observations is shown in relation to elevation. A peak is visible at an elevation of approximately 1850 meters, while fewer observations were recorded at elevations below 1600 meters or above 2000 meters.

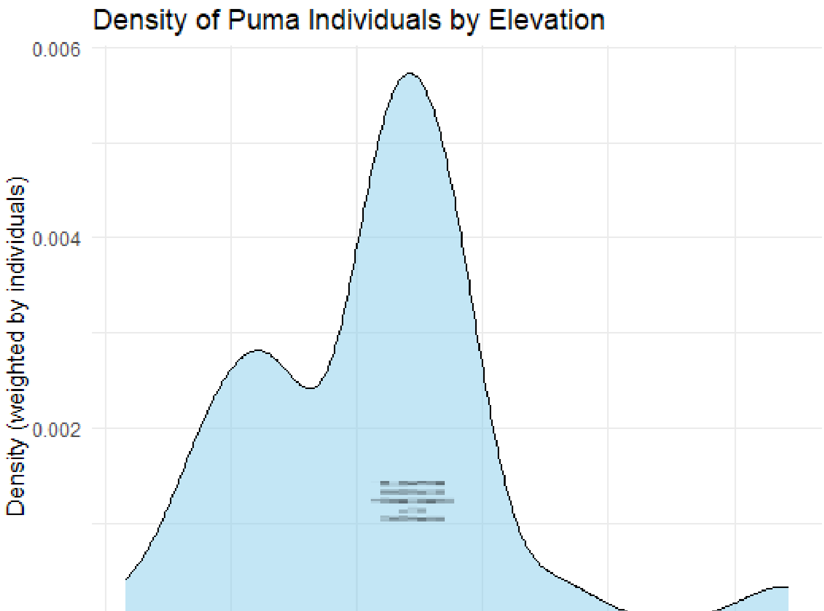
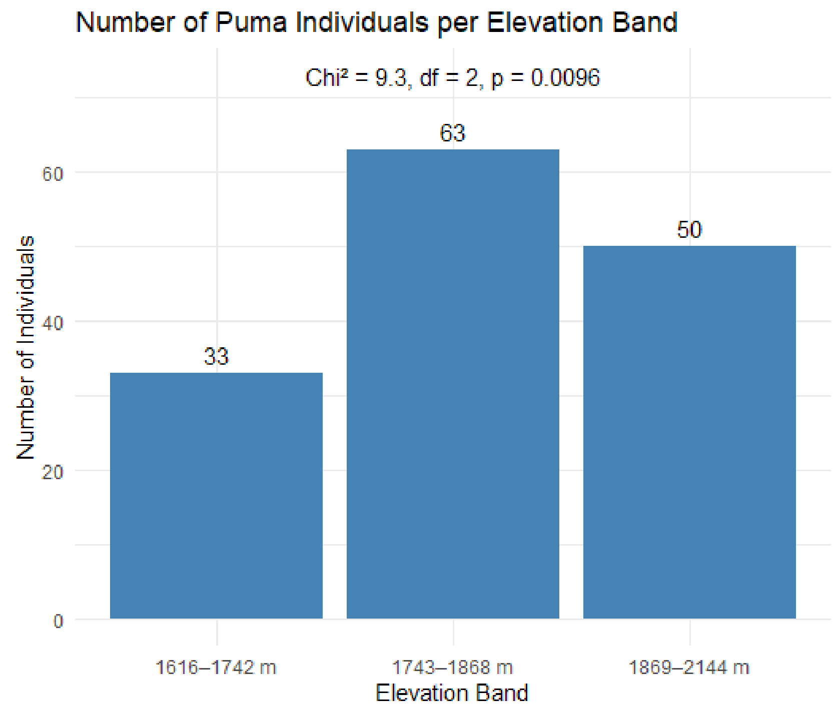


Figure 8. Puma observation density across elevation gradients (2015-2025)

Figure 9 presents the number of puma observations across different elevation bands. Higher elevation bands recorded more observations, with 63 observations in the 1743–1868 m band and 50 in the 1869–2144 m band. In contrast, the lower elevation band (1616–1742 m) recorded 33 observations. Statistical analysis revealed a significant correlation between the number of puma observations and elevation band (Chi-squared test, p = 0.0096).



Seasonal variation

To analyze seasonal variation, data from the period 2015–2025 were used. Figure 10 illustrates the number of puma observations recorded each year. A significant correlation was identified between the year and the number of puma observations (Chi-squared test, p < 0.001). The highest number of observations occurred in 2023, with 51 records, followed by a notable peak in 2018 with 32 observations. As of now, 12 puma observations have been recorded in 2025.

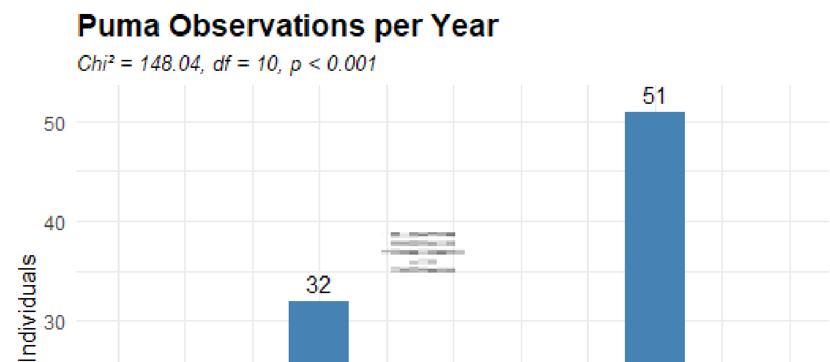


Figure 10. Puma observations per year

Figure 11 presents the number of puma observations per month, based on data collected between 2015 and 2025. Each month is categorized according to its corresponding season. A clear peak in puma activity is observed in April (30 observations) and June (25 observations). In contrast, July and October show the lowest levels of activity, with only 5 observations each. Statistical analysis indicates a significant association between the month and the number of puma observation (Chi-squared test, p = 3.09e-08).

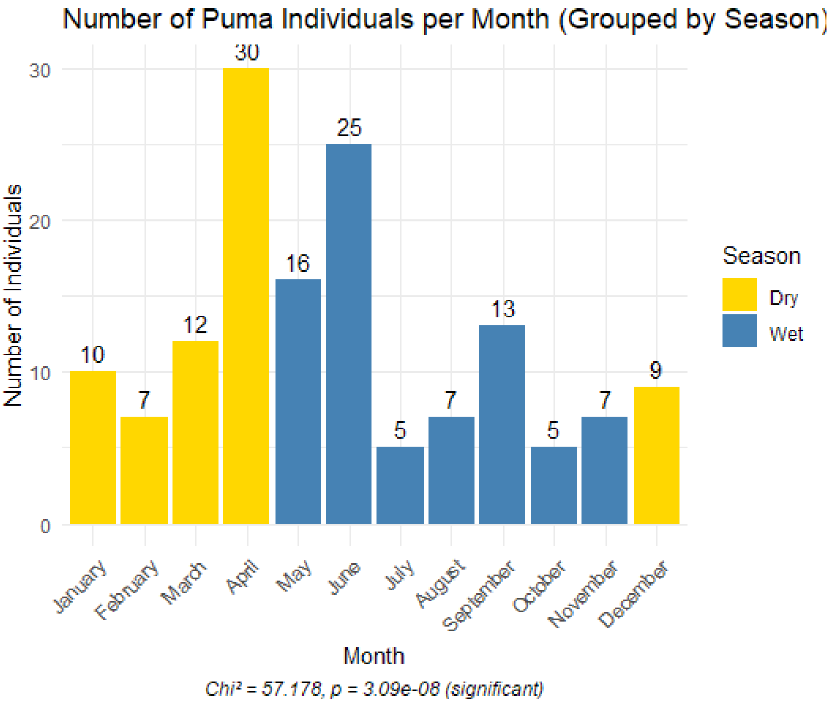
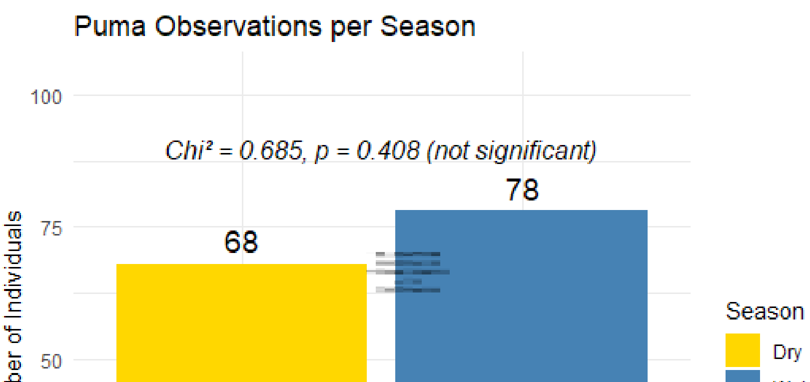


Figure 12 presents a comparison of puma observations between seasons. A slightly lower number of observations was recorded during the dry season (68 observations) compared to the wet season (78 observations). However, this difference was not statistically significant (Chi-squared test, p = 0.408).



Prey presence

Data on the distribution of puma prey species were collected during the 2024–2025 period and compared with puma observations from the same timeframe. Figure 13 illustrates the relationship between the total number of prey observations and the total number of puma observations. A positive association is observed, indicating that higher prey abundance corresponds with an increased number of puma observations. This relationship was found to be statistically significant (Linear regression test (t-test), p = 0.00919).

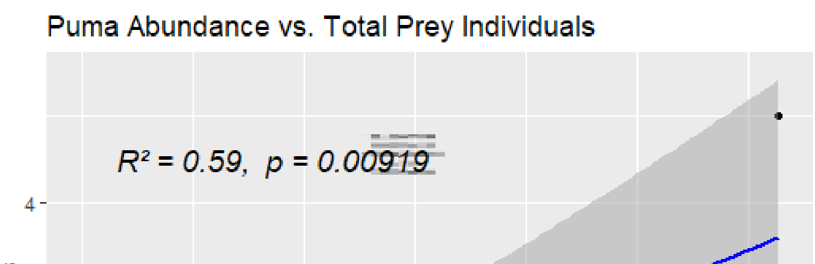
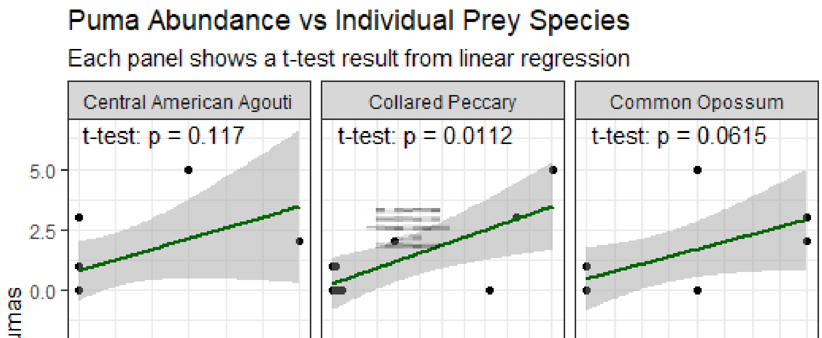
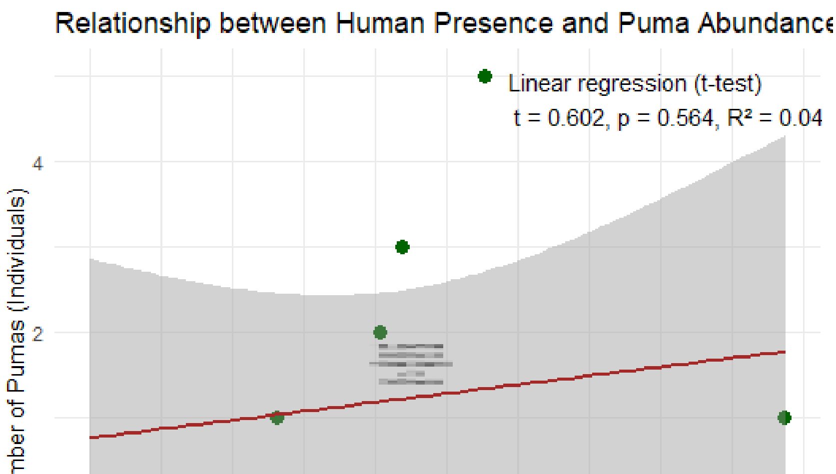


Figure 14 compares puma observations from 2024–2025 with the six most likely and frequently encountered prey species. A weak to strong positive relationship is observed between the number of puma observations and each of the six prey species. Data analysis revealed two statistically significant relationships: with the collared peccary (linear regression test (t-test), p = 0.0112) and the white-nosed coati (linear regression test (t-test), p = 0.00445). No significant relationships were found for the remaining prey species: the Central American agouti (linear regression test (t-test), p = 0.117), the common opossum (linear regression test (t-test), p = 0.0615), Dice's cottontail (linear regression test (t-test), p = 0.624), and the paca (linear regression test (t-test), p = 0.721).



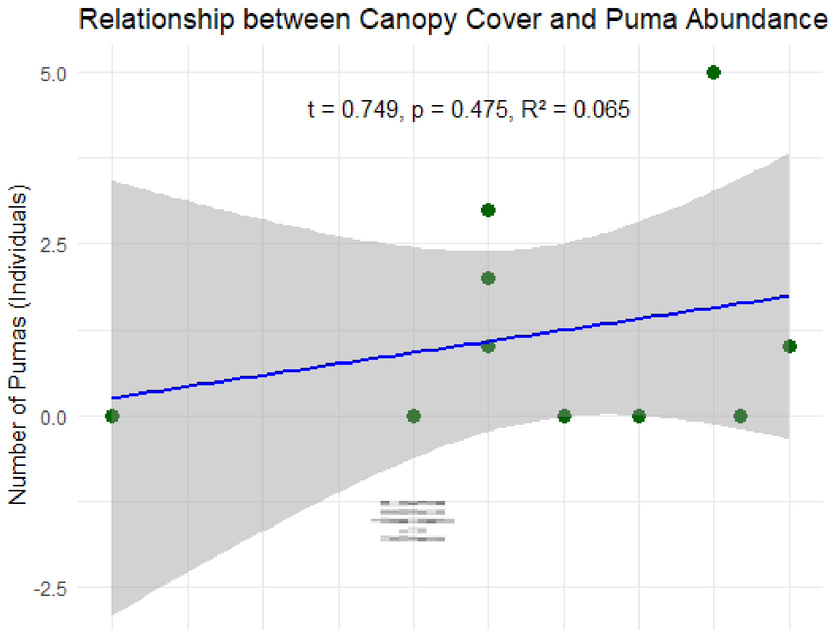
Human presence

During the 2024–2025 period, the number of human observations per camera location was also recorded. This dataset was compared to the number of puma observations from the same timeframe. Figure 14 illustrates this relationship, showing a slight positive correlation between the number of human and puma observations. However, this relationship was not statistically significant (linear regression test (t-test), p = 0.564).



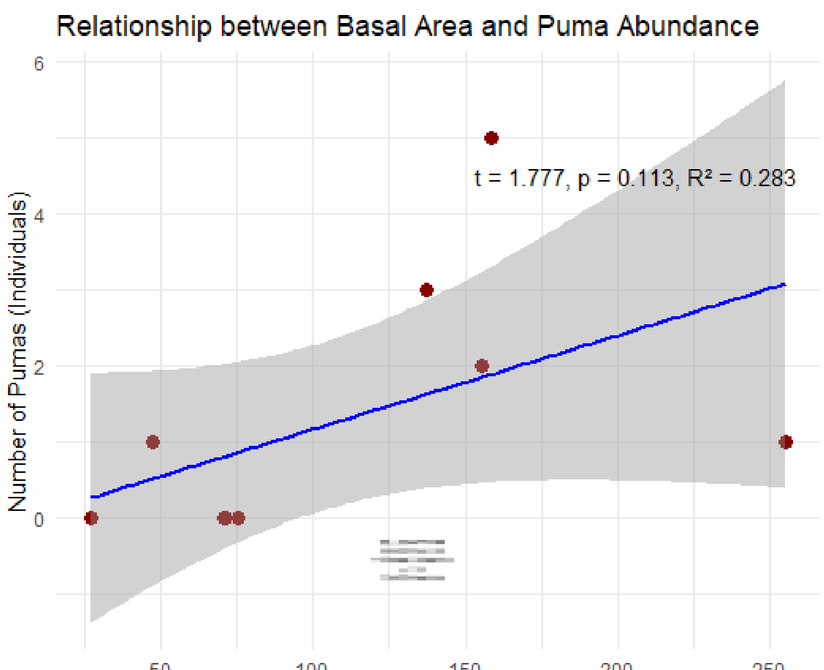
Canopy cover

Canopy cover was measured per location in 2025. These results were compared with the number of puma observations recorded in 2024–2025. Figure 16 illustrates the relationship between canopy cover and the number of puma observations. A slight positive correlation is visible, however this relationship was not found to be statistically significant (linear regression test (t-test), p = 0.564).



Forest density

Forest density plots were measured at each camera location in 2025. These data were compared with the number of puma observations recorded during the 2024–2025 period. Figure 17 illustrates this relationship. While a positive correlation is observed, it was not found to be statistically significant (linear regression test (t-test), p = 0.113).



Discussion

Several conclusions can be drawn from the results. In addition, an analysis was conducted to understand why certain outcomes occurred as they did. This involved examining whether specific factors may have influenced the results during the study. Both certainties and uncertainties were taken into account in this evaluation.

It is important to note that the number of pumas does not necessarily represent different individuals. The database records the number of individuals per observation, which in most cases is a single individual. It is relatively rare for multiple pumas to be observed on a camera trap at the same time. A key challenge in researching pumas is that individuals are often difficult to distinguish from one another. Therefore, it is possible that the same individual was recorded multiple times on one or more cameras. As mentioned earlier, pumas have large territories, making it likely that the same individual was observed at multiple camera locations.

Camera locations

The results indicate that pumas were only observed at five camera trap locations: E2, E3, G3, M3, and M4. No statistically significant differences were found between these locations. This may be due to the limited amount of puma data available, which makes it difficult to detect clear patterns across camera locations. The low number of observations could be attributed to frequent technical issues with the camera traps during the 2024–2025 period. Cameras that did not record any puma activity were often those that malfunctioned. Some cameras failed due to heavy rainfall, others recorded continuously and thus collected footage without any wildlife detections, and in some cases, SD cards were faulty or cameras were repeatedly triggered by moving vegetation. In contrast, camera traps such as E2 functioned consistently throughout the research period, allowing for continuous detection of animals. This likely explains why E2 had the highest number of puma observations.

In addition, the number of camera traps installed varied across trails. For example, the Jilguero trail had three cameras, while Gavilan and Montaña each had two, and Don Victor, Los Quetzales and Sentinel were equipped with only one. This uneven distribution may have led to biased data regarding observations per trail.

For future research, it is essential that camera traps function reliably to ensure consistent wildlife detection. The operational integrity of the cameras is a top priority, particularly given the humid conditions of the cloud forest. Regular field checks of the cameras and SD cards, as well as having spare cameras available, are crucial. Proper positioning of the camera traps also requires attention to ensure that various animal species are clearly captured. This is particularly important for comparisons and analyses involving felid species. Additionally, the camera's field of view should be free from vegetation or other elements that may trigger false detections. Finally, standardizing the number of camera traps per trail would help maintain data consistency across locations.

Forest type

As previously mentioned, forest type can influence habitat preference and, consequently, the distribution of pumas. Due to the denser canopy, thicker undergrowth, and more mature trees in old-growth forest, it was expected that this forest type would offer more shelter, food, and hiding places for mammals compared to planted forests. Natural regrowth forests are younger than old-growth forests and therefore have a much less complex structure. As a result, they may appear less suitable or attractive to carnivores.

However, the results indicate that the highest number of puma observations occurred in natural regrowth forest, followed by old-growth forest. This relationship was also found to be statistically significant. One possible explanation is that prey availability tends to be higher in natural regrowth forests. For herbivorous prey species, the presence of more young plants is more appealing than the typically woody vegetation found in old-growth forests (Whitfeld et al., 2012). A higher abundance of prey could lead to increased puma presence as well.

The study by Coon et al. (2020), however, provides a contrasting view. They report that pumas prefer habitats with dense vegetation that support their stalk-and-ambush hunting strategy over those with higher prey densities. It may be that pumas in the Cloudbridge Nature Reserve prioritize prey abundance, given the significant positive correlation found between prey observations and puma presence.

Between 2015 and 2025, a total of 24 camera trap locations have been active or are still active. Of these, 10 were placed in old-growth forest, 9 in natural regrowth forest, and 5 in planted forest. Although this distribution is uneven, with more camera traps placed in old-growth and natural regrowth forests than in planted forest, this is justifiable as only a small area of the Cloudbridge Nature Reserve consists of planted forest. The number of camera trap locations in old-growth and natural regrowth forests is roughly equal, which indicates that the higher number of observations in natural regrowth forest is not likely caused by a difference in sampling effort.

It is possible that repeated sightings of a single individual puma in natural regrowth forest may have contributed to the higher observation count. Natural regrowth areas may also function as corridors or hunting grounds rather than core habitat. However, the same could be argued for old-growth forest.

In conclusion, significantly more puma observations were recorded in natural regrowth forest compared to the other forest types. Several possible explanations for this have been provided, but further research is needed to confirm or refute these findings.

Elevation

Although the elevation range between the lowest camera trap (1616 m) and the highest camera trap (2144 m) was relatively limited at 528 m, significant differences in puma observations across elevation bands were nonetheless found in the 2015–2025 dataset. Most observations occurred in the higher elevation bands, with the highest number in the middle band (1743–1868 m). While little research has been conducted on the effect of elevation on puma distribution, it is in line with expectations that pumas are more frequently observed at higher elevations. The study by Bevilacqua et al. (2023) in the Cloudbridge Nature Reserve confirms that larger mammals such as pumas are more commonly found at higher altitudes.

Despite the significant relationship between puma observations and elevation, further research is certainly recommended. Due to the large territory size of pumas, elevation preferences may vary depending on the region. Finding reasons for this could be highly valuable in expanding knowledge and improving puma conservation efforts. Comparing elevation to other factors may also be useful in this regard. The theory that pumas prefer higher elevations due to the presence of higher-altitude, suitable old-growth forest habitat is not supported by this study. Pumas were more frequently observed in natural regrowth forest, which is generally located at lower elevations within the Cloudbridge Nature Reserve.

Seasonal variation

The results show that the number of puma observations per year between 2015 and 2025 differed significantly. The reason why 2023 had such a high number of observations (51 in total) is because additional cameras were installed in the reserve that year for other projects. As a result, the comparison with other years is not valid and introduces bias. It is possible that 2018 also had more cameras in place, but no information is available to confirm this. Additionally, there may have been more issues with camera malfunctions in some years compared to others. In 2024–2025, for instance, several cameras broke down, which meant that some locations could not deliver data for extended periods.

Puma observations were also compared across the months of the year. This analysis revealed that April and June had the highest number of puma observations, while July and October had the lowest puma activity. These results also proved to be statistically significant. The peaks in April and June are not fully understood. One possible explanation could be the transition season from dry to wet, which occurs between April and June. Prey species such as collared peccaries are observed more frequently during this transition period. Due to the arrival of rain and lower temperatures, water and food availability increases, which may lead to greater activity in collared peccaries (Hofmann et al., 2016). However, this study took place in the northern Pantanal in Brazil, so the environmental conditions for peccaries are not exactly the same as in the Costa Rican cloud forest. The potentially increased activity of puma prey species could explain the higher puma activity during the transition season. This would be an interesting topic for further research.

When puma observations were compared between seasons—dry versus wet—no significant relationship was found. The number of puma observations did not differ strongly between the two seasons. This may suggest that pumas do not necessarily prefer one season over another. However, further research would be needed to confirm this.

Prey presence

The results show a positive and significant correlation between the number of puma observations and the total number of prey species observations. This correlation aligns with expectations based on existing literature, as previously mentioned.

When the individual prey species were analyzed in relation to puma observations, the results varied. A significant correlation was found between puma presence and the number of collared peccary and white-nosed coati observations. However, no significant relationship was found for the other four prey species: Dice’s cottontail, paca, Central American agouti, and common opossum.

Several explanations may account for this outcome. First, collared peccaries and white-nosed coatis were recorded far more frequently than the other prey species. With larger datasets, it is generally easier to detect significant patterns. However, it is also possible that the other prey species were simply less present in areas where pumas were active. Additionally, coatis and peccaries are larger animals compared to species like the cottontail or paca. Peccaries and female coatis also tend to live in groups, which may result in group detections on camera traps. Cameras are more likely to detect frequent movements by groups than solitary movements of smaller prey species.

Another explanation could be that pumas, peccaries, and coatis share similar habitat preferences, leading to overlapping activity patterns. In summary, there are several possible explanations for these findings, but further research on the predator-prey relationship of pumas is needed to explore this more thoroughly.

Human presence

No significant correlation was found between the number of human observations and the number of puma observations. Although the relationship was not statistically significant, a slight positive trend was observed, indicating that more pumas were seen in areas where more people were also observed. This contradicts findings from earlier studies, which suggest that human presence negatively affects puma behaviour. Pumas are generally known to avoid humans (Logan & Sweanor, 2001).

One possible explanation for this discrepancy is that all camera traps in this study were placed along trails. These trails are frequently used by both visitors and researchers. Pumas also tend to use these paths, likely because like humans they prefer easy-to-navigate routes over dense, difficult terrain. Since no cameras were placed off-trail, it remains unknown whether pumas may be more active in areas without human presence and whether they actively avoid people in such locations.

Because no significant relationship was found in this study, it would be valuable to further investigate this dynamic. Future research should consider placing camera traps off-trail to better assess whether pumas indeed avoid humans when alternative routes are available.

Canopy cover

As previously mentioned, canopy cover is a factor related to forest density and forest type. It is an important element as it provides shelter, breeding and nesting spaces, food resources, and helps both predators and prey remain hidden (Spencer et al., 2005). Canopy cover may therefore influence mammal diversity and abundance, although its effect on large mammals such as pumas has not yet been thoroughly studied.

In this study, an attempt was made to examine the relationship between canopy cover and the number of puma observations. However, no significant relationship was found. It is possible that using the CanopyViewer app alone is not sufficient for accurate measurement, or that a larger number of measurements is needed to build a robust dataset. Further research is therefore necessary, either to expand the canopy cover measurement method or to explore the topic in greater depth.

Forest density

Forest density may also play a role in puma distribution. Previous research suggests that pumas prefer habitats with higher forest density, as this supports their ambush hunting strategy (Coon et al., 2020). However, the results of this study did not show a significant relationship between forest density and puma observations.

A larger dataset could provide a clearer picture of the different habitat types within the Cloudbridge Nature Reserve. Additionally, all measurements in this study were taken along trails, where forest density is logically lower than deeper within the forest. Ideally, camera traps would be placed in the interior of the forest, where forest density and other factors could be measured more accurately. However, due to the steep and slippery terrain, this is not considered safe or practical.

For future research, it would be valuable to collect more forest density data, potentially from a wider range of locations, to gain better insight into how this variable influences puma distribution.

Conclusion

The aim of this study was to gain a better understanding of the distribution and habitat use of the puma in the Cloudbridge Nature Reserve. The research focused on the spatial distribution and habitat preferences of the puma. In connection with this, the effects of several factors on puma distribution and habitat use were examined: forest type, elevation, seasonal variation, prey abundance, human abundance, canopy cover, and forest density.

Significant relationships were found between puma presence and both forest type and elevation. Most observations occurred in natural regrowth forests and at mid- to high elevations. Puma activity also showed seasonal variation, with peaks in April and June, possibly linked to changes in prey behaviour during the transition from dry to wet season. Prey abundance, especially of collared peccaries and white-nosed coatis, showed a significant positive correlation with puma observations. No significant relationship was found with human presence, canopy cover, or forest density, though trail-based data may have limited these results.

This project contributes to global nature conservation by using standardized camera trap methods aligned with international monitoring practices. By focusing on species like pumas, key indicators of ecosystem health, the study generates data with relevance beyond the local scale. Local research of this kind is essential for identifying broader ecological trends in tropical forests and can support conservation goals set by international organizations. In doing so, it shows how small-scale studies can play a meaningful role in protecting global biodiversity.

Despite several interesting findings, much remains unclear about the distribution and habitat use of the puma in Cloudbridge Nature Reserve. Further research is needed to explore this in more detail.

Recommendations

Ensure camera reliability

Test all cameras beforehand and carry backups. Use weatherproof models to prevent data loss due to rain or malfunction.

Standardize camera use

Keep cameras active for equal durations and log any changes. Maintain consistency to strengthen long-term datasets.

Balance camera placement

Distribute cameras evenly across forest types and trails to improve representativeness.

Improve camera positioning

Mount cameras at knee height, clear the view, and avoid areas with moving vegetation or water to reduce false triggers.

Include off-trail locations

Place some cameras off-trail to assess puma activity in low-human-disturbance zones.

Expand vegetation measurements

Increase canopy and density sampling, including off-trail, to better capture habitat structure.

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