Tropical dry-forest canopy cover and fruits presence as determinants of spatial distribution of *Saguinus geoffroyi*'s during the dry season in Parque Metropolitano, Panama.

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RESUMEN EJECUTIVO

La cobertura del dosel arbóreo del bosque tropical seco y la presencia de frutos como determinantes de la distribución espacial de Saguinus geoffroyi durante la estación seca en el Parque Natural Metropolitano, Panamá.

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La deforestación a gran escala debido a la continua urbanización ha llevado a la fragmentación de los bosques secos tropicales, hábitat de muchas especies de animales. Un ejemplo de esto es *Saguinus geoffroyi* Pucheran 1845 o mono tití que ha tenido que adaptarse al aislamiento en un bosque seco tropical secundario en medio de la Ciudad de Panamá como lo es el Parque Natural Metropolitano. Debido a esto, consideramos importante entender los determinantes de la distribución de *S. geoffroyi* en el Parque Natural Metropolitano para saber cómo sostener su población. Para esto intentamos responder la siguiente pregunta: ¿Cuál es el nivel preferido de cobertura del dosel arbóreo, la demografía de la población, el tamaño de la tropa, el tamaño del territorio geográfico y los recursos alimenticios del *S. geoffroyi*? Creíamos que encontraríamos mayor nivel de cobertura de dosel y más presencia de frutas en árboles maduros del bosque tropical y que por ende estos árboles serían los hábitats preferidos para esta especie.

La colecta de datos se realizó aleatoriamente en los senderos: Mono tití, Los Caobos, La Cienaguita, El Roble y Los Momótides durante los meses de febrero a abril de 2018. Georeferenciamos todos los puntos de detección de *S. geoffroyi* con un sistema de GPS, anotamos la siguiente información: tiempo, el número de tropas y el número de individuos en

cada tropa y tomamos fotos del dosel arbóreo. Seguidamente, identificamos la especie de árboles en los que se detectaban a los monos y determinamos si eran árboles maduros del bosque tropical. La población total se estimó utilizando una fórmula utilizada en estudios anteriores.

En total obtuvimos un resultado de 15 detecciones con un total de 90 individuos observados. El promedio de grupos observados por día fue de 1,36 con un promedio de 6 ± 2,14 individuos por grupo. Estimamos una población total de 135 individuos y 23 grupos. La Cienaguita fue el sendero con más avistamientos, en total 11. Sin embargo, en el sendero Los Momótides no encontramos ningún individuo. Creemos que esto se debe a la localización de los senderos con respecto a las carreteras principales y la conectividad entre los árboles durante la época seca.

Encontramos que la abundancia de monos aumenta en niveles entre 61% y 80% y que en promedio habitan un nivel de dosel arbóreo de 75,86 %. No encontramos una relación clara entre la abundancia de monos y la presencia de frutas o árboles maduros del bosque tropical. Creemos que esto se debe a la la variabilidad estacional de la dieta y a la variada dieta de estos monos que incluye: insectos, frutas y exudados o resinas de los árboles. Con respecto a la vegetación, nuestro estudio observó la presencia de S. geoffroyi principalmente en las siguientes especies de árboles: Espavé (*Anacardium excelsum*), Guácimo colorado (*Luehea seemanii*) e Indio Dormido (*Ficus insipida*), con una clara preferencia hacia el Espavé. Este último siendo el árbol más abundante en el Parque Natural Metropolitano y con una mayor producción de frutos durante la estación seca y es una fuente de calcio es importante para esta especie.

Concluimos que el determinante principal de la distribución de *S. geoffroyi* durante la época seca en el Parque Natural Metropolitano es un nivel arbóreo alto y que los frutos y los árboles maduros del bosque tropical no son buenos predictores de la preferencia de su hábitat.

EXECUTIVE SUMMARY

Tropical dry-forest canopy cover and the presence of fruits as determinants of the distribution of S. geoffroyi during the dry season at Parque Natural Metropolitano, Panamá.

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Large-scale deforestation due to the continued urbanization of Panama City has led to the fragmentation of tropical dry forests, the habitat of many animal species. An example of this is *Saguinus geoffroyi* Pucheran 1845 or Geoffroy´s tamarin, a monkey species that has had to adapt to habitat fragmentation in a secondary tropical dry forest in the middle of Panama City as is the Parque Natural Metropolitano. We considered important to understand the determinants of the distribution of *S. geoffroyi* in isolated area such as the Parque Natural Metropolitano and thus know how to sustain its population. We tried to answer the following question: What is the preferred level of canopy cover, the population demography, the troop size, the geographical territory size and the food resources of S. geoffroyi? We predicted that we would find a higher level of canopy cover and more presence of fruit in mature trees of the tropical forest and that these trees would therefore be the preferred habitat for this species.

The data collection was carried out randomly in the trails: Mono tití, Los Caobos, La Cienaguita, El Roble and Los Momótides during the months of February to April 2018 in Parque Natural Metropolitano. We mapped all the points of detection of *S. geoffroyi* with a global

positioning system (GPS) and recorded the following information: time, the number of troops and the number of individuals in each troop and took pictures of the canopy cover. Next, we identified the species of trees on which the Geoffroy's tamarins were seen on and determined if the vegetation used was mature tropical forest trees by measurements of the diameter and the crown size. The total population was estimated using a mathematical formula.

We obtained over the course of this experimentation 15 detection events and a total of 90 individuals. The average number of groups observed per day was 1.36 ± 0,92 with an average of 6 ± 2,14 individuals per group. The total population was estimated to be of 135 individuals and 23 groups inside the park's area. La Cienaguita was the trail with the most sightings, 11 in total. However, we did not find any individual in Los Momótides. We propose that this is due to the location of the trails with respect to the main roads and the connectivity between the trees during the dry season.

We also found that the abundance of monkeys increases in levels between 61% and 80% and that on average they were ubicated in a canopy cover level of 75.86% ± 9.66%. We did not find a clear correlation between the abundance of monkeys and the presence of fruits or the presence of mature trees of the tropical forest. We believe that this is due to the varied diet of these monkeys that includes insects, fruits, and exudates and due to the seasonal variation of food availability. With respect to the vegetation, our study observed the presence of S. geoffroyi mainly in the following tree species: Espavé (*Anacardium excelsum*), Guácimo colorado (*Luehea seemanii*) and Indio Dormido (*Ficus insipida*), with a clear preference towards the Espavé. The latter being the most abundant tree in the park and with greater fruit production during the dry season as well as being an important calcium source for this species.

In summary, the main determinants of the distribution of *S. geoffroyi* during the dry season in the Parque Natural Metropolitano is a high level of canopy cover. The presence of fruits and mature trees of the tropical forest are not good predictor variables of the preference of their habitat.

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Time Allocation

Number of full days in the field: 5.5*

Number of full days dedicated for the project: 26

* 1 workday considered to be 8 hours. Hours do not include travel time required to get to and from field sites

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Introduction

Tropical dry forests are one of the most threatened ecosystems in Central America and are disappearing at an alarming rate (Murphy & Lugo, 1986; Janzen, 1988; Sorenson & Fedigan, 2000). According to Miles et al. (2006), only 1.7% of the original tropical dry forest area remains in Central America. The depletion of these ecosystems is mostly due to extensive deforestation to create cattle pastures, timber, and human settlements (Skinner, 1986). This large-scale deforestation reduces habitat area, increases landscape patchiness, decreases patch size, and increases patch isolation (Fahrig, 2003). As human development continues to grow, studies of species that have succeeded to adapt themselves in perturbed and fragmented habitat are important to improve our ability to sustain these animal populations (Pucheran, 1845).

Saguinus geoffroyi Pucheran 1845 is a neotropical primate of the family Callitrichidae and has showed a certain tolerance to disturbed environments (Moynihan, 1970; Díaz-Muñoz, 2010) and offers many benefits to disturbed forests (Hladik, 1969; Skinner, 1986; Díaz-Muñoz, 2010). The complexity of tropical forests is partly maintained by primates, because they allow an uncommon dispersion of seeds by endozoochory and, consequently, aid in regenerating forests specifically in fragmented habitats (Skinner, 1986; Pruitt, 2016). However, very little research has been done on *S. geoffroyi* foraging in habitat fragments (Kupsch et al., 2014). Parque Natural Metropolitano is a fragmented habitat near Panama City where population of *S. geoffroyi* prevails. Studying how *S. geoffroyi* can sustain their populations in such habitats can provide more insight on how one can better manage fragmented habitats. In addition, studying *S. geoffroyi'*s most common food sources and habitat use can offer a better understanding of their habitat preference and their distribution (Pruitt, 2016).

Literature review

Study species

S. geoffroyi, known by its common name Geoffroy´s tamarin or Mono tití in Panama is a small neotropical primate that ranges from the Chocó region of Colombia along the Pacific coast of Panama to the eastern side of Azuero peninsula (Moynihan, 1970; Wilson et al., 2005). They are mostly found in secondary growth and forest edges (Moynihan, 1970; Dawson, 1979; Defler, 2004; Díaz- Muñoz, 2010). *S. geoffroyi* was considered as a subspecies of *Saguinus oedipus,* Linnaeus (1758)*,* but its separation was accepted by Skinner (1986)*,* Moore (1992) and Defler (2004) based on physical differences in the cranial and facial structures of both groups.

Adult *S. geoffroyi* are typically 225-240 mm tall, weigh between 450-500 grams and live in group sizes of 5 to 10 individuals (Dawson, 1970; Sussman, 2000). *S. geoffroyi* have 3 main food sources: insects, small fruits and buds, and plan exudates. Their diet changes seasonally and depending on availability (Hladik & Hladik, 1969; Garber, 1980). Exudates from the tree *Anacardium excelsum*, commonly known as Espavé and found in Parque Natural Metropolitano, are a very important food resource for *S. geoffroyi* (Garber, 1980; Skinner, 1985).

Skinner (1985) estimated the relative abundance and status of habitat of *S. geoffroyi* at different sites in Eastern Panama from August to October of 1983. The study showed that *S. geoffroyi* densities were greater where human access was limited, and that numbers and spacing between selected canopy tree species affect *S. geoffroyi´s* density. During the study, the monkeys were often seen in large trees, which usually become "emergent" in old forests. The importance of tall forest and other structurally similar habitats was also shown to be important in the study of Wallace (1998). These trees provide food, predators avoidance, and act as sleeping sites or transit routes. The protection from aerial predators that offers forest structure to callitrichids has been widely studied and have shown that callitrichids are particularly more vulnerable to birds of prey (Izawa, 1978; Ferrari, 1990). As a result, previous research has shown the importance of the canopy characteristics which can protect Geoffroy's tamarin population against these airborne predators (Izawa, 1978; Madden et al., 2010).

Madden et al., (2010) examined how the canopy connectivity and the availability of food resources have influenced habitat selection by *S. geoffroyi.* This monkey spends much of their time foraging for food in fragmented areas interconnected by lateral branches or other type of vegetation (Garber, 1993; Madden et al., 2010). *S. geoffroyi* need to satisfy the high nutritional demands related to their small body size and high metabolic rate (Garber, 1992). Optimal foraging is often highly related to the habitat selection of S. *geoffroyi* since suitable canopy characteristics and runways can provide a more efficient food intake (Madden et al., 2010). Despite the high number of studies examining the behavioural foraging patterns of *S. geoffroyi*, it is not clear what characteristics of the canopy habitat might be of importance in determining to distribution of this small monkey in tropical forests.

Current study

This study attempted to shed a light on the main reasons determining distribution of *S. geoffroyi* over an environment. According to previous studies, the habitat preference of *S. geoffroyi* is determined mainly by two factors: the canopy characteristics and the presence of food (Madden et al., 2010). Thus, this study aimed to examine these two predictor variables of abundance to better understand the use of the territory of Parque natural Metropolitano by *S. geoffroyi.*

We observed the preferred level of canopy cover, the population demographics, troop size, geographic territory size of S. geoffroyi and observed the fruit presence in the trees used by *S. geoffroyi* in Parque Natural Metropolitano, a secondary tropical dry forest of Panama. We predicted that *S. geoffroyi*´s abundance would be higher in areas where the level of canopy cover and the abundance of fruits were high which would be indicators of *S. geoffroyi*´s habitat preference. We also thought that these two predictor variables would be seen more often in mature tropical forest trees.

This study 1) observe patterns of abundance of *S. geoffroyi* population through the level of canopy cover as well as the food presence on different trees and 2) look at the possibility that mature tropical forest trees offer an accented presence of these predictor variables. We considered the presence of *S. geoffroyi* in an habitat as an indicator of its preference for the characteristics of this habitat. We measured the canopy cover when an *S. geoffroyi* detection event occurred and this characteristic acted as a proxy to determine canopy routes for monkeys and protection from aerial predators. Secondly, fruit presence was assessed by identifying the vegetation they used through a list of tree species that Geoffroy's tamarins feed in (Table 1). The tree species in which the Geoffroy's tamarins were observed were noted and then the absence or presence of fruits in this tree was noted. Afterwards, we determined if the trees were considered as mature tropical forest trees by measuring the trees diameter and crown size.

Methods

Study site

The data collection was conducted in Parque Natural Metropolitano during the dry season during February, March and April of 2018. The precise days of data collection are shown in Table

3. Metropolitan parks are an important refuge for wildlife in developed areas (Rompré et al., 2008). The Parque Natural Metropolitano (PNM), is located in Ancon, Panama City at *8º 59' 45,15" N and 79º 32' 48,35" W*. Its altitude ranges from 50-150 msnm. The PNM has an approximate area of 232 hectares, 4,7 kilometers of trails and it is part of the Biological Corridor along with nearby parks such as Soberanía National Park and Camino de Cruces National Park (ANAM, 2014). These parks are segmented by Via La Amistad, which impedes animals, especially arboreal animals, from crossing between the parks (Mi Ambiente, 2016). According to ANAM (2014) the area of study is classified as a semi-deciduous tropical forest- high intervened and is considered as a Key Biodiversity Area (KBA).

Trail mapping

Trails of Parque Natural Metropolitano were mapped using Garmin GPSMAP 62sc system, Garmin Base Camp, and Google Earth. The same GPS settings than McNaughton, 2015 were used.

Transect

The methodology used in this study followed the guidelines established by Peres (1999) in which they standardized the transect method used for primate studies. The standardized methods consist in cutting trails, performing surveys during activity peak of the monkeys during 6:30 to 7:00 am until 10:30 or 11:00 am, briefly stopping during walking to avoid background noise and collecting pertinent information when the individuals are detected (Table 2.). However, the transects established in this study were modified in the sense that they could follow the trails of the park. This is primarily due to time limitations and to avoid destroying a protected habitat by cutting new trails. Censuses in the afternoon were avoided because could underestimate *S.*

*geoffroyi'*s densities. The diurnal behavior of S. *geoffroyi* makes their populations less detectable during the afternoon (Peres, 1989b; Peres, 1999).

Each of the five trails in Parque natural Metropolitano were considered as a transect and each was assigned a number from 1 to 5 (1-Mono Tití, 2-La Cienaguita, 3- Los Caobos, 4-Los Momotides, 5-El Roble) (Figure 1). A random number generator was used to know in which order the trails had to be walked during each trial.

Data collection

At the beginning of each day, the date and the weather conditions, such as cloud cover and temperature, were recorded. Additionally, the transect identity, start time and end time of each walk were also noted. Transects were walked slowly and every 100m, brief stops were performed to decrease background noise by the data collectors for the purpose of detecting auditory cues from monkey troops. Once a detection event occurred, a GPS point was established, and the following data was recorded: time, group size, number of juveniles, canopy cover estimation, vegetation and fruit analysis, behavior of each individual (foraging (F), resting (R) or moving (M)). We used the same definitions as Guo (2007) for the behavior of each individual. Individuals pursuing or eating food were defined as foraging. Individuals resting were defined by a sedentary comportment during the observation and moving individuals by a walking, running or jumping activity. In the field, waypoints were marked using Garmin GPSMAP 62sc. The GPS points were named as Mono#, where the # is the group number. Perpendicular distance of the exact location where an animal (or a group of animals) was first detected from the trail was also measured (Peres, 1999).

Canopy cover estimates

Subsequently, an approximate of canopy cover where the individuals were seen was recorded via photographic documentation. A picture of the canopy where Geoffroy's tamarins were found was taken for each detection event. Pictures were processed in GIMP version 2.8 to distinguish the sky from the canopy and obtain a percentage of the number of pixels representing the canopy cover. Canopy cover estimates were used to provide a better idea of habitat use and preference by *S. geoffroyi.*

Vegetation identification and fruit presence

The tree species in which the primates were encountered was recorded during the study which occurred in the dry season. The species identified included the species in which the Geoffroy's tamarins were found on or through which the monkeys were foraging, feeding, or moving. A field list of the tree species in which the Geoffroy's tamarin have been seen to feed on in previous studies was created (Table 1) (Garber, 1980; Skinner, 1989). The presence or absence of fruit was also noted at each tree. Secondly, we determined if the trees were mature tropical forest trees. This was done by measuring the diameter at breast height (dbh) and by estimating the crown size of the tree. Trees exceeding 75 cm in diameter and a crown spanning over 20 meters or more in width were considered mature trees.

Population estimation

The formula used to determine an approximate of the park's *S. geoffroyi* population(N) was:

$$N=\frac{n\times s\times A}{a}$$

where n is the average number of groups observed, s is the average number of individuals in each group, A is the park's total area, and a is the area surveyed. The area surveyed is calculated by averaging the initial distance of detection from the trail and adding that distance as a buffer on either side of the trail.

Data analysis

The GPS points for each observation of a Geoffroy's tamarin troop were inputted on a basemap from satellite image and each point was used to perform a density map according to the number of individuals seen at this same point. Representation of the distribution of *S. geoffroyi*´s populations in the park were produced with the use of ArcMap. This also allowed us to determine a preferred habitat in the park by the monkey´s populations through visual representation. We regressed *S. geoffroyi* abundance in each group with the level of canopy cover using a linear model in Excel to observe if our ability to count the individuals decreased as the canopy level increases.

Code of Ethics Certification

All research was carried out following the Code of Ethics of McGill University (see Appendix III for certificate).

Results

Population demography

Data collection was done over a period of 11 days for a total of 44 hours during the dry season in February and March 2018. Over the course of this study it was possible to obtain 15 detection events (Table 3). The average number of individuals perceived in each group was 6 ± 2,14 and a total of 90 individuals were observed. Cienaguita highlighted the higher level of sightings with 11 sightings. It was possible to observe 2 groups of *S. geoffroyi* in Caobos, one group for each Roble and Mono tití, and no detection event occurred in Momótides (Table 3). The average distance of detection from the trail was 14,93 ± 12,85 m. The average number of groups seen per day was 1,36 ± 0,92. The total length of the five trails walked was 4,7 km and the total park area was 232 hectares. With all this information, we were able to run the formula to calculate the *S. geoffroyi* population density which gave us a value of 135 individuals. Considering the average group size as being 6, the park could have around 23 groups within its boundaries.

Canopy cover estimates

An average canopy cover of 75,86 % ± 9,66 % was found. The figure 5 shows that 9 sightings occurred in a canopy cover ranging from 61 to 80 % and 5 were recorded in a canopy cover above 81% which demonstrates a preference for moderately high canopy levels. No significant difference was observed in the canopy cover level from trees that were mature trees and the ones that were not (Figure 6).

Vegetation identification and fruit abundance

The study observed the vegetation primarily used by the monkeys and found seven tree species being used during this study: *Anacardium excelsum, Luehea seemanii, Ficus insipida, Enterolobium cyclocarpum, Sterculia apetala, Bursera simarumba,* and *Astronium graveolens* (Figure 7). The study allowed to show a clear vegetation preference for *Anacardium excelsum, Luehea seemanii*, and *Ficus insipida* which respectively obtained 9, 5, 4 observations on total of 20 trees being used by the groups observed. The tree on which the monkeys were detected primarily were measured in order to know if they were mature tropical forests trees. A percentage of 53% of mature trees was obtained on 15 measured trees which do not show a clear preference from the monkeys to this type of vegetation (Figure 4). Our second predictor variable being the fruit presence also showed that 53% of the trees where monkeys were observed had fruits which once again do not show any trend. The fruit presence was observed predominantly in mature trees with a percentage of 75% (Figure 6). However, canopy cover level was not higher in these trees. The figure 8 at the correlation between the number of individuals in the group observed in relation to the canopy cover of the site. We observe a slight decrease in the level of canopy cover in as the number of individuals in the group increases.

Discussion

The data substantiate the first premise of our hypothesis which predict a higher abundance of *S. geoffroyi* in a high level of canopy cover (Figure 5). The second statement, predicting a higher presence of *S. geoffroyi* in trees harboring a fruit presence during the dry season, was questionably true (Figure 3). The study uncovered no relationship between a higher level of canopy cover in mature tropical forest trees. However, mature trees of tropical forests could be a reliable predictor of the fruit presence (Figure 6).

The preference of *S. geoffroyi* for elevated levels of canopy cover can indeed be explained by the protection from aerial predators the canopy cover procures (Izawa, 1978; Cane, 1993; Madden, 2010). Previous studies have shown that the canopy connectivity could also increase the available routes for travel and decrease the foraging time. The canopy cover is most of the time a good indicator of canopy connectivity and would provide the same benefits (Madden et al., 2010). Niche partitioning could be greater in forests with high level of canopy cover, thus, increasing the global diversity of the system and the food resources for *S. geoffroyi* (Madden et al., 2010). We did not see any differences in the level of canopy cover analyzed between mature tropical forests trees and the one that were not. This highlights that mature trees are not good indicators of a higher presence canopy cover. In other words, they do not provide an increased level routes for travel, protection for aerial predators, etc. This could in part explain the reason why we did not observed more groups in mature trees versus the ones that were not, since they do not provide the benefits of an higher level of canopy cover. Figure 8 shows that a slight increase in the level of canopy cover decreases the number of individuals we counted, and this could be that the visibility was better to count the monkeys in a more open canopy. This brings the idea of possible miscounts as canopy increases since the number of individual counted decreases.

The second predictor variable being the fruit presence could not explain solely the habitat use because the habitats used by *S. geoffroyi* can also harbor other resources that are consumed by the species. It has previously been shown that this monkey species has a mixed feeding strategy exploiting ripe fruits, insects, and plant exudates (gums) throughout the year (Skinner, 1985). Hladik and Hladik (1969) and later Sussman (2000) showed that insects were more predominant and constituted a larger part of the monkey's diet during the dry season. Additionally, dry season usually because a decrease in the fruit availability which may switch their diet patterns (Digby et al., 2007). The reason of an higher presence of fruits in mature trees remains unknown to our knowledge. The figure 6 also shows that the error bars overlap and as a result, there might not be relationship between these two variables. Factors such as chance could also arise since of the paucity of the detection events we have.

In our study, *S. geoffroyi* seemed to prefer the tree species *Anacardium excelsum* during the period sampled in the dry season. This statement is supported by Garber (1984) and Skinner (1985) who found that *Anacardium excelsum* phenology had its fruiting season from February until May and is an important feeding source of *S. geoffroyi.* Garber 1984 highlighted that *Anacardium excelsum* is a major source of seasonal dietary calcium and could be a required element in *S. geoffroyi'*s habitat components. Parque Natural Metropolitano is an important reservoir of *Anacardium excelsum*. This statement substantiates the importance of the park in providing an habitat for *S. geoffroyi*. The tree species *Luehea seemanii,* which was the second most used tree species, is also a species on which *S. geoffroyi* feed (Table 1). However, *Ficus insipida*, the third most used species, is not found in the diet *S. geoffroyi* according to the table 1. In two cases out of five, *Ficus insipida* was located in a strategic place where the monkeys could reach an *Anacardium excelsum* and a *Luehea seemanii*, both abundant in fruits. As a result*, Ficus insipida* might be mainly used for diverse reasons such as for travel or because it has a good level of canopy connectivity. Another possibility is that they could be using it as another source of food eating the leaves, the insects or the exudates as it has been reported in other monkeys (Hladik & Hladik 1969).

S. geoffroyi distribution

Clear trends in the spatial distribution of *S. geoffroyi* were found where several groups utilized the same area. The figure 2 shows the area in which the density of monkey was higher. The detection events nearly all occurred in the trail Cienaguita whereas none eventualized in Momotides. This could be attributed to Cienaguita´s location being the trail with greater continuing area of forest (Figure 1). On figure 2, we observe a dominant hotspot of the monkey presence in Cienaguita. This hotspot is situated in a hollow next to the highest point of the park and could offer a microclimate and a dominant food presence that brings monkey. Among the observations in Cienaguita, 80% showed a fruit presence which could support the previous statement of increased food resources in Cienaguita. Momótides could be avoided by the groups due to its location and the size of the area. Moreover, the area is surrounded by roads which makes it difficult and dangerous to access and the fruiting feeding trees are found in low proportions (Mcnaughton, 2015). Alteration of habitat due to forest fragmentation can alter the structure of the forest habitat (Arroyo-Rodríguez and Mandujano, 2006) also the construction of the north corridor Juan Pablo II which separates Momótides from the other trails. Mono tití trail only have one detection event probably due to the physical characteristics of the area. During our study we observed that the Mono tití trail has more deciduous trees during the dry season compared to the rest of the trails, as a result this area tends to be drier. However, according to many park guards, the beginning of the Mono tití trail near the road was a common place to observe the monkeys even if we did not see any (J. Bonilla, Personal communication, April 2018). Also, many other parts of the park were pointed as good to observe monkeys, however, during different seasons. The director of the park, Dionora Viquez, pointed out that the monkeys were mostly ubicated in Momótides during the rainy season (D. Viquez, Personal communication, April 20, 2018). The reason behind the low number of detection events in Roble and Caobos remains still ambiguous. Possible reasons are that Roble is next to a large amount of anthropogenic activity which can interfere with the monkeys' vocalizations and that Caobos have only small and scare patches of fruiting trees.

Through park guard personal communications, we learned that the groups of *S. geoffroyi* had a daily route which they use each day, but that will vary with the season (J. Bonilla, Personal Communication, April 2018). This route is used to connect the different fruiting trees and food resources to the sleeping trees. This suggests a spatial memory of *S. geoffroyi* over the territory which has been shown in closely related species of *S. geoffroyi* by Garber (1989). If they use the trail on a daily basis, it could explain why many observations occurred in the same area of the park. However, this premise has not been studied in the scientific literature in our knowledge.

Population status

A total of 135 individuals were estimated to live in the park which gives an average of 23 groups of *S. geoffroyi*. However, from this result, we cannot infer if the individuals were resident or transient groups. Defler (2004) published a range of *S. geoffroyi* territory sizes and population densities. He estimated the territory sizes for the species to range from 9,4 Hectares to 26 hectares. Considering that the park area is 232 hectares, the higher number of groups possible from his estimates could be 25 groups and the lower limit of 9 groups. As a result, our estimate fit the ranges of Defler (2004) and each group would have an average territory size of 10,08 hectares which is close to the smallest territory size found by his study. This could be due to the fact that the park is constrained by the roads and by the anthropogenic activity that surrounds it, and this increases the difficulty of extending their territory.

Limitations and future recommendations

The lack of power in our study arises principally from the paucity of samples. Monkey detection events are difficult to obtain since the animal are very scarce on the territory and have large territory sizes. The seasonal changes in food availability is an important consideration since it influences the territory sizes and locations of *S. geoffroyi* (Madden, 2010). This statement, demonstrated in previous studies, means that the data collected is only representative of the time frame of this study being the months of February and March. The study took place during the dry season and deciduous trees had lost their leaves. Patches of deciduous or evergreen trees were found in the park and have probably influenced the distribution of *S. geoffroyi* across the territory. More field study should be performed at different time of the year. A more comprehensive understanding of the ubication of the monkeys is profitable for the park since the information can be used for touristic activities.

The spread of the groups could be indeed very large and incorporated an uncertainty about the monkey counts. As one can see in figure 8, the number of individuals counted increased as the canopy cover decreased which suggests possible miscounts. Undoubtedly, bias occur by the fact that monkeys can have been counted repeatedly.

We were limited by the status of the park as a protected area which restricted the transects lengths and shapes. Thus, only a small sample of the park was analysed. Moreover, the transect lengths were not all the same, introducing bias in sampling time and comparison among trails.

Future studies would benefit from incorporating techniques allowing the differentiation of the groups such as camera traps. As well monitoring the feeding behaviors and movements throughout the year seems to be of importance since the monkeys' spatial pattern change with the season. According to the guards of the park, it would be important to investigate in depth the common routes monkey use since they might have a predetermined route used on a daily basis. We consider that looking at the possible arboreal routes available for the monkey to move between Parque Natural Metropolitano and Parque Camino de Cruces is crucial. This is important since it allows a transfer of individuals, in order words, a gene flow in the population.

Conclusion

The current study showed through a modified transect method that among the two predictor variables, the canopy cover was a reliable indicator of the *S. geoffroyi* abundance, however the fruit presence was inadequate. The possible justification comes from the fact hat *S. geoffroyi* have a diversified diet which varies constantly according to the season. An insect-based diet might be more prevalent during the dry season since of an increased availability of large insects and lower abundance of fruits. We predicted that both predictor variables would be prevalent in mature tropical forest

trees although only the fruit presence followed this statement. The data collected in this study indicated a possibility of 135 individuals distributed in the park. This study highlighted the inclination of *S. geoffroyi* to occupy the tree species *Anacardium excelsum*. Parque Natural Metropolitano is an important sanctuary for the *S. geoffroyi* populations due to its important density of *Anacardium excelsum*. However, the diet of S. geoffroyi is subject to change depending on the time of the year and the results may differ if the experiment is performed again. Thus, to understand the full extent of the possible patterns of distribution and the use of food resources of S. geoffroyi, future studies should ideally incorporate a complete monitoring of the populations over more than a year.

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Appendix I: Figures

Figure 1. Trail location within the park. Inset is location of Parque Natural Metropolitano in relation to Panama City. Photo from Google Maps, 2015 and Google Earth 2016. (Pruitt, 2016)

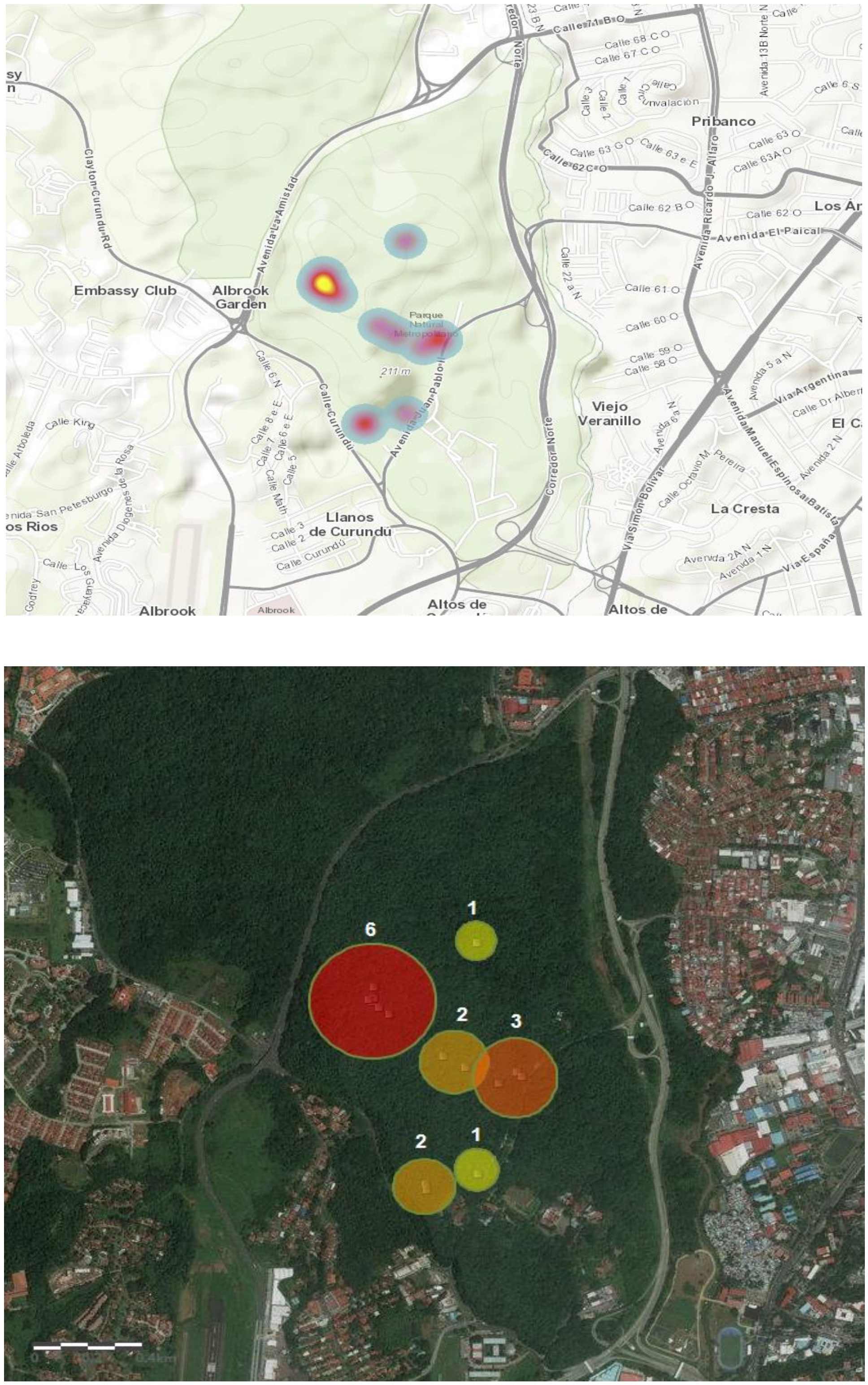

Figure 2. (Up) Density map of *S. geoffroyi* groups in Parque Natural Metropolitano. (Down) Dot density of all detection waypoints. Photo from GISonline 2018.

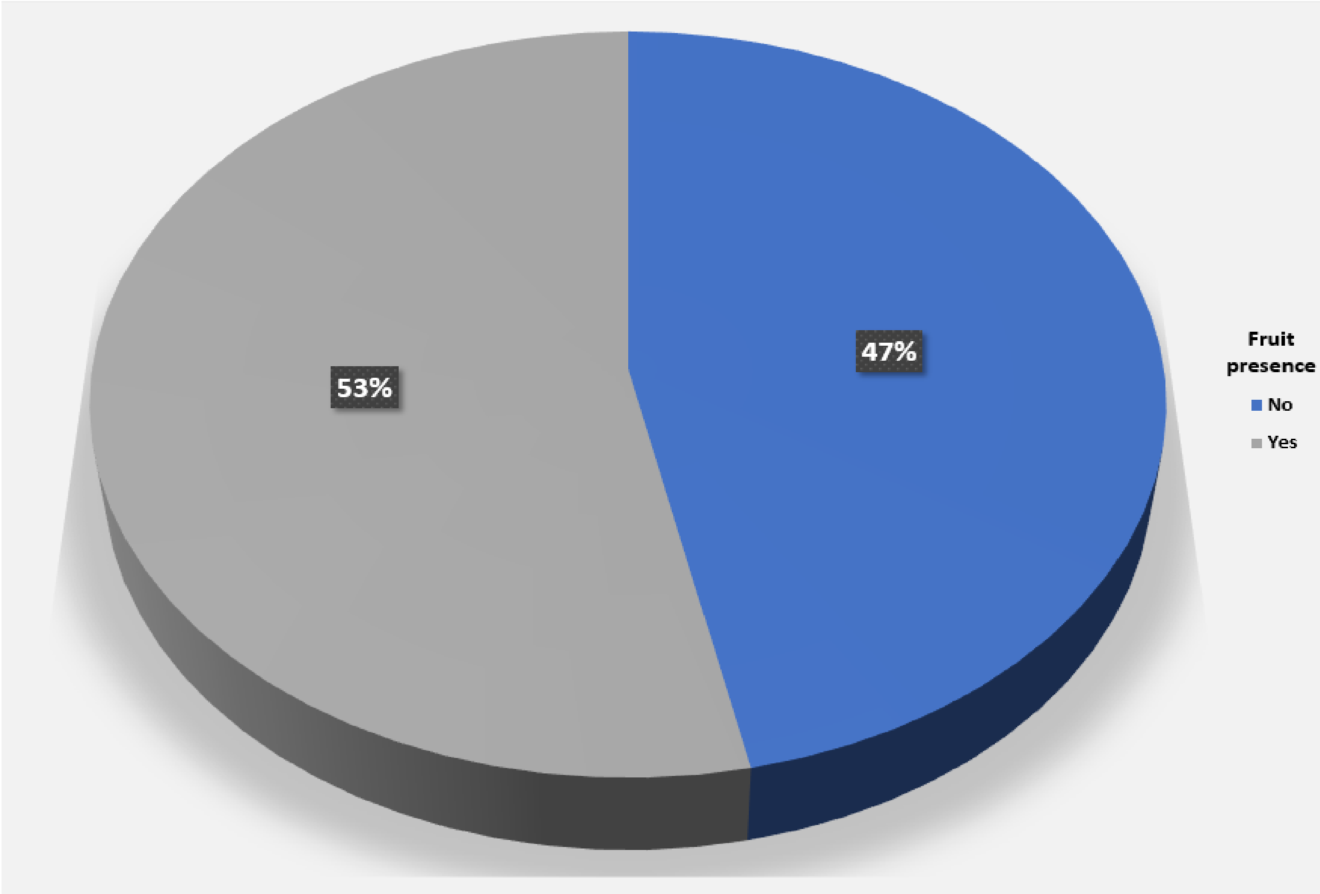

Figure 3. Prevalence of S. geoffroyi to use trees harboring a fruit presence

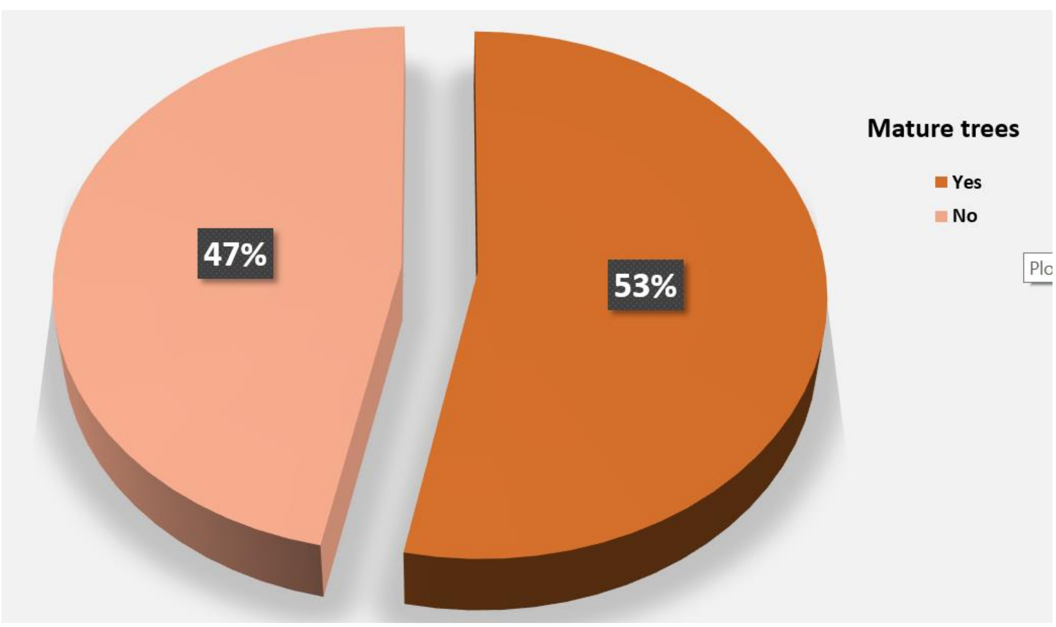

Figure 4. Prevalence of *S. geoffroyi* to use mature tropical forest trees for displacements

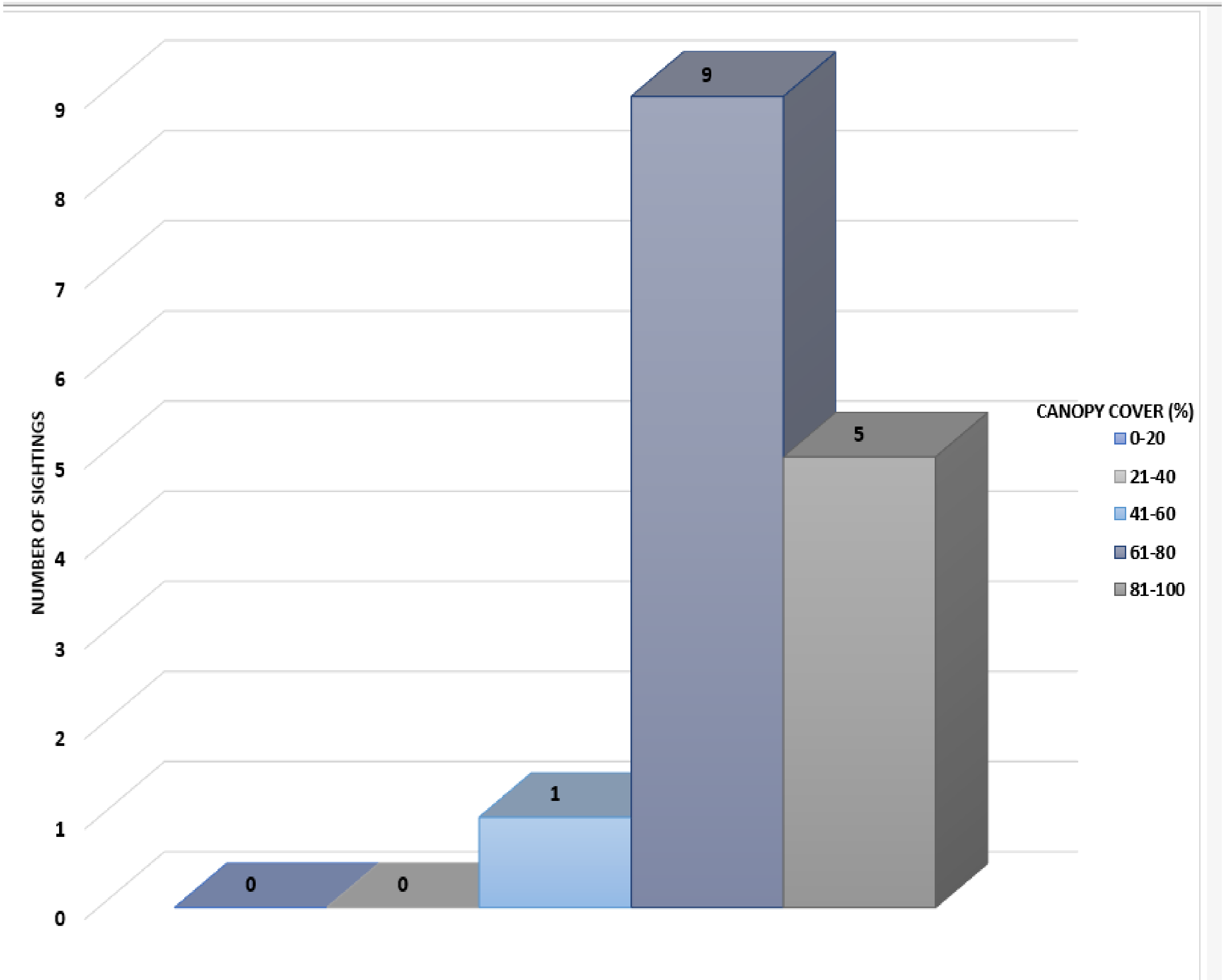

Figure 5 **:** Observations of the level of canopy cover observed at the detection event site

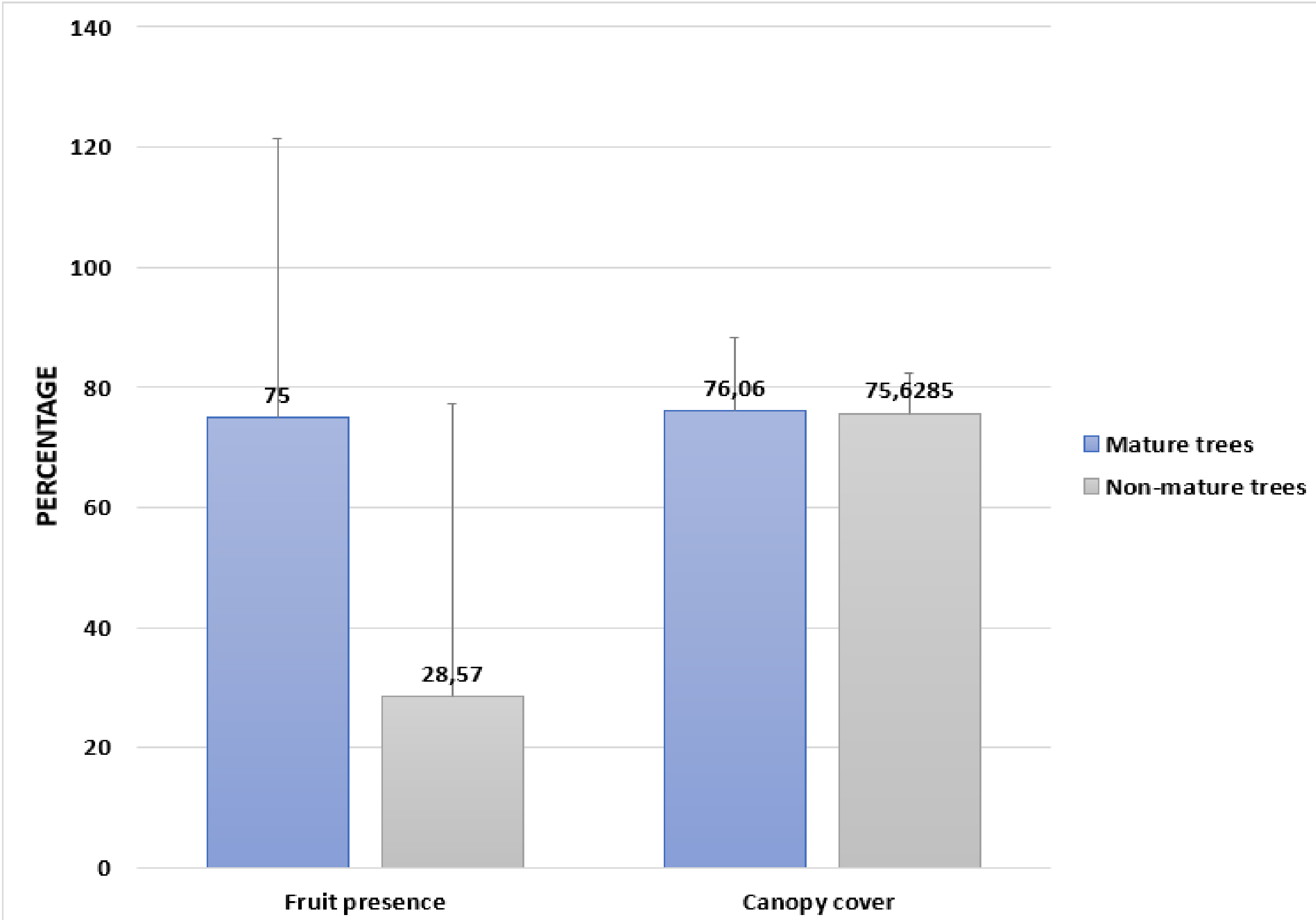

Figure 6. Comparison between mature tropical forest trees and normal trees for the prevalence of prevalence of fruit and canopy cover.

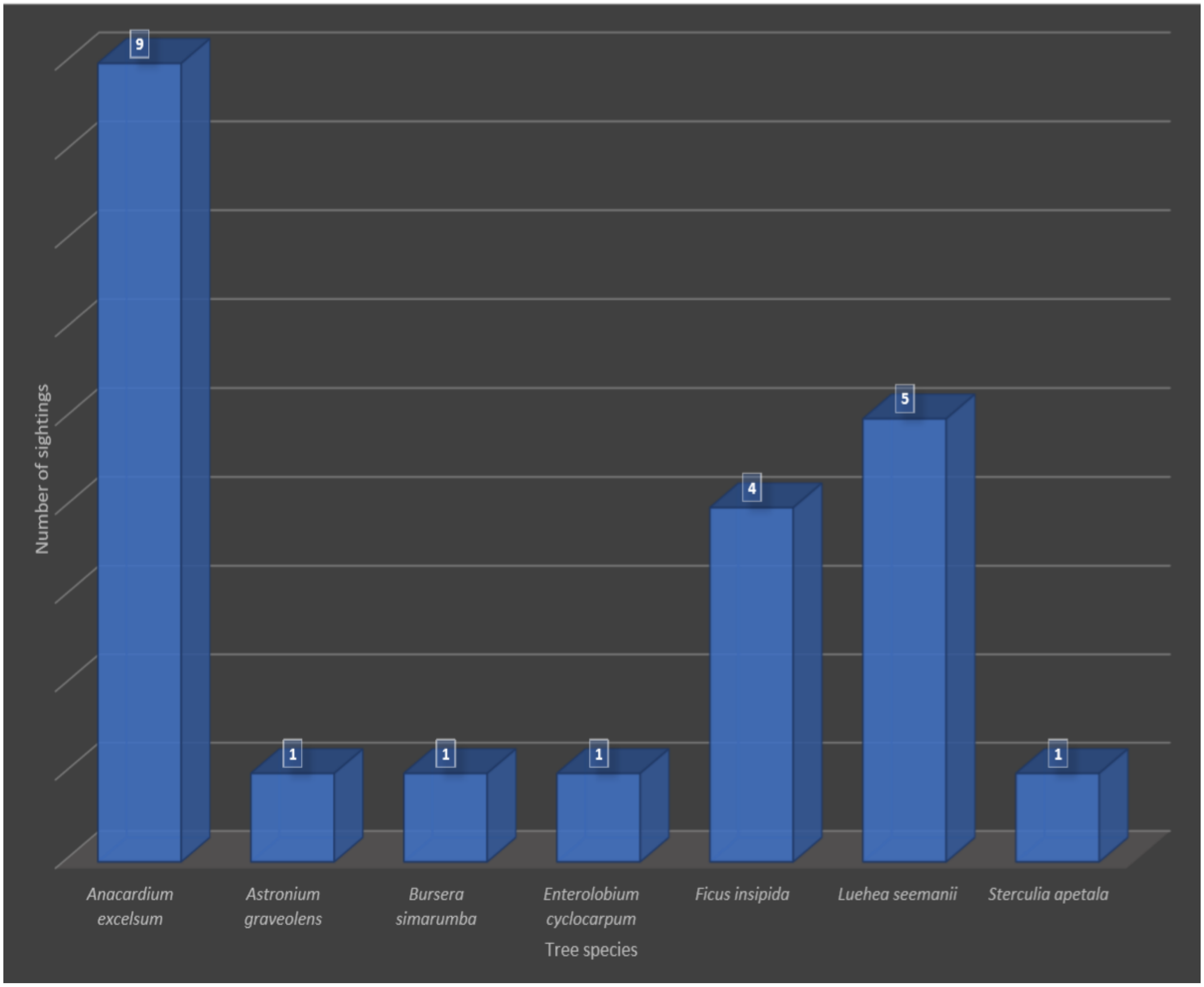

Figure 7. Tree species on which *S. geoffroyi* groups were found to be on or to be moving on**.**

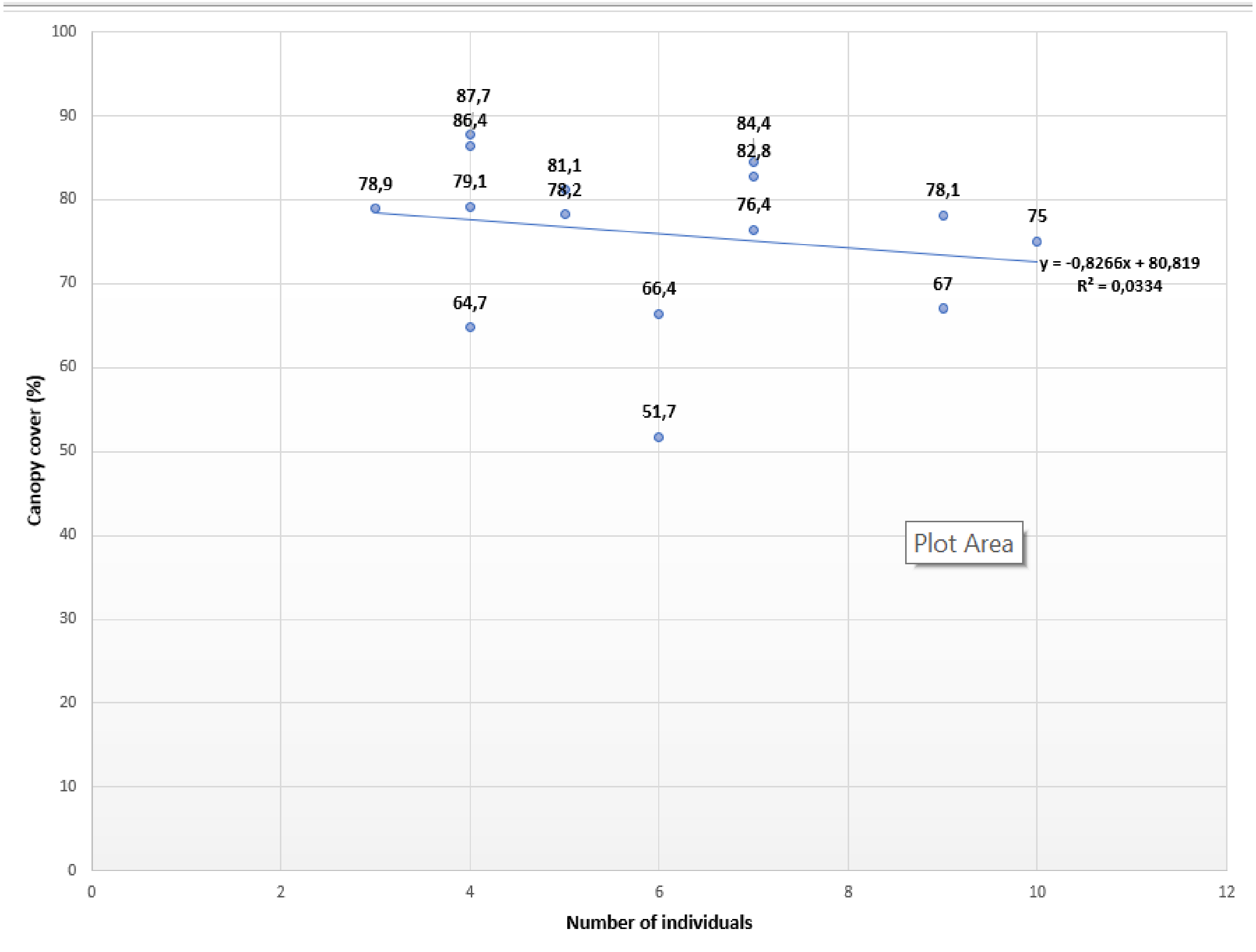

Figure 8. Relationship between the number of individuals detected according to the level of canopy cover observed at the detection event site**.**

Appendix II - Tables

Table 1: Identified plant species in the diet of Saguinus geoffroyi from previous studies (Skinner 1985)

Anacardium excelsum	*Govania lupuloides*
Annona spraguei	*Guazuma ulmifolia*
Anntirrhoea tricantha	*Guranta sp.*
Apeiba tibourbou	*Inga hayessi*
Apeiba tilleacea	*Inga punctate*
Bactris major	*Luehea seemanni*
Brysonima crassifolia	*Miconia argentea*
Byrsonima spicata	*Peritassa pruinose*
Cardulovica palmata	*Phyllanthus acuminatus*
Cecropia peltata	*Posoquierta latifolia*
Costus guanaiensis	*Prockia crucis*
Dendropanax arboreus	*Spondius mombin*
Dimerocostus stobilaceus	*Xylopia aromatica*
Genipa americana	

Table 2: Direct observations following a detection event

Date	Number of individuals	Tree diameter
Time	Number of juveniles	Percent canopy
GPS point	Behavior	Dominant vegetation used by tamarin
Altitude of terrain	Tree crown size	Fruit abundance

Table 3 **:** Date and time of detection event of the *S. geoffroyi* groups.

Date	*GPS point name*	*Trail*	*Time*	*Coordinates*
February 19, 2018	Mono1	Roble	07:35	N08°59,213' W079°32.'430
February 19, 2018	Mono2	Cienaguita	09:13	N08°59,266' W079°32.745'
February 19, 2018	Mono3	Cienaguita	09:45	N08°59,504' W079°32.862'
February 20, 2018	-	-	-	-
February 21, 2018	Mono4	Caobos	07:17	N08°59,197' W079°32.873'
February 21, 2018	Mono5	Cienaguita	08:03	N08°59,456' W079°32.992'
February 21, 2018	Mono6	Cienaguita	08:50	N08°59,595' W079°32.959'
February 22, 2018	Mono7	Cienaguita	08:46	N08°59,636' W079°32.976'
February 23, 2018	Mono8	Mono titi	07:40	N08°59,739' W079°32.769'
March 12, 2018	Mono9	Caobos	08:51	N08°59,184' W079°32.870'
March 13, 2018	Mono10	Cienaguita	08:10	N08°59,449' W079°32.688'
March 14, 2018	Mono11	Cienaguita	10:49	N08°59,422' W079°32.724'

March 15, 2018	Mono12	Cienaguita	08:01	N08°59,606' W079°32.976'
March 22, 2018	Mono13	Cienaguita	07:35	N08°59,578' W079°32.943'
March 22, 2018	Mono14	Cienaguita	07:55	N08°59,613' W079°32.975'
March 23, 2018	Mono15	Cienaguita	08:25	N08°59,612' W079°32.986'

Appendix III - Certifications


Groupe en éthique de la recherche
Piloter l'ethique de la recherché humaine
EPTC 2: FER

Certificat d'accomplissement

Ce document certifie que

Jasmin Bourgault

a complété le cours : l'Énoncé de politique des trois Conseils : Éthique de la recherche avec des êtres humains : Formation en éthique de la recherche (EPTC 2 : FER)

18 janvier, 2018