A habitat suitability study for sloth species *Bradypus variegatus* and *Choloepus hoffmanni* in Cloudbridge Nature Reserve, Costa Rica.

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February 2018
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Research into the suitability of the cloud forest habitat of Cloudbridge Nature Reserve for the Hoffman's two-toed sloth and Brown throated three-toed sloth.

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This report is written in the scope of the major internship in year four of Wildlife Management.

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Preface

I am thankful for the people who gave me the chance to set up and carry out my own research in the cloud forest of Costa Rica. First of all, Jennifer Powell who helped me with setting up the research, helped me with questions or problems I had while I was executing the research and for contacting different reserves and animal centres in order to improve my research.

Tom Gode who also took time to help me, by thinking of different ideas to broaden and improve my research and also with contacting people around Costa Rica.

Last, I want to thank all the volunteers and fellow researchers in Cloudbridge Nature Reserve who assisted me with carrying out my fieldwork.

Abstract

Costa Rica is one of the countries with the highest biodiversity in the world. But this has been under threat because of deforestation in the 19th century. Nowadays the government is doing a lot to stop this from happening again and to protect the forests, ecosystems and the wildlife. 25 percent of Costa Rica is appointed to National park or reserve. Cloudbridge is a nature reserve that is privately owned. Cloudbridge has done a lot of reforestation and the goal of the reserve is to get it back to a climax cloud forest state. Most of the reserve has been reforested, however sloths did not yet significantly recolonise the reserve. This is why the management of the reserve considers to reintroduce sloths back into the area. The aim of this research is to get insight in the suitability of the habitat at Cloudbridge Nature Reserve for both sloth species (*Bradypus variegatus* and *Choloepus hoffmanni)*. With the main question being: is Cloudbridge Nature Reserve suitable for sloth species *Bradypus variegatus* and *Choloepus hoffmanni*? Sub questions are looking at the suitability of the climate, the most suitable habitat, if there are threats and the possible density that sloths could live in. Also a soft-release process was described to inform the management of Cloudbridge.

The research area is located near the village of San Gerardo de Rivas in the Talamanca Mountains of southern Costa Rica at the border of Chirripó National Park. The elevation in the reserve varies from 1550m to 2600m. There are four types of habitat present in Cloudbridge Nature Reserve, primary forest, natural regrowth older than 30 years, natural regrowth younger than 30 years and planted forest.

To find the most suitable habitat 20 transects were researched, with four transects in each habitat class. The transects were 100 meters long and 8 meters wide. For each transect, all tree species with a DBH above 15 cm were identified and the suitability, height, DBH, canopy class, vine development, and canopy temperature of the tree were noted down. For climate, threats and density other researches and literature were used. To gather information on the soft-release process, different animal centres were contacted and also one was visited.

Values were given to each factor for each transect, to be able to find the most suitable transect. These values were multiplied with different percentages depending on their importance. All these outcome were added together, the one with the highest score is the habitat and transect that is most suitable for sloths. The climate is considered to be suitable for both species, since they live in similar conditions in other reserves. The most suitable habitat type is natural regrowth over 30 years old and the most suitable transect is SF2, this transect has the most amount of suitable trees and the highest trees. The second most suitable transect, which together with the first one stands out above the others, has the most suitable species, the second highest score on the amount of suitable trees. The only threat is the presence of predators. The possible density that sloths can live in the most suitable habitat, which is a size of 65.09 hectares, is for the Hoffmann's two-toed between 5 and 97 sloths and for the brown throated three-toed between 39 and 813 sloths.

Overall, Cloudbridge Nature Reserve is found suitable for both sloth species.

Contents

1. Introduction

In terms of biodiversity, Costa Rica is in the top 20 countries in the world. While only covering 0.03% of the world's surface, it contains 4% of the species on earth. The geographic location of Costa Rica is one of the reasons for this. It is situated between two big continents and has coastlines on two different oceans (Costa Rica Guides, 2011). Another reason for the high biodiversity is that the government of Costa Rica is actively protecting the natural habitats of its country. However, this was not always the case (Delfina Travel Group, Inc, 2017).

In the 20th century, large parts of the forests in Costa Rica were cut down. Around the 1940's, forest covered almost 75 percent of the land in Costa Rica, which mainly consisted of tropical rainforest. In the decades that followed, major parts of this forest was logged, leaving only 26 percent forest cover by 1983. Nowadays, 52 percent of Costa Rica's land is covered with forest. This is mainly because the government understands the importance of forest ecosystems and the services they provide (Blasiak R., 2011). To preserve and protect the current ecosystems and biodiversity, around 25% of Costa Rica's land is appointed as National Park or Reserve (Anywhere, Inc, 2016). These protected areas in tropical regions are important to prevent deforestation, and they are also effectively protecting the ecosystems and species within the protected areas (Bruner A., 2001).

Cloudbridge Nature Reserve is a privately owned protected area that is devoted to conserving and reforesting the cloud forest. Before Cloudbridge was founded, the area was mainly farmland, but the reserve has been replanting and regenerating the forest. The goal of the reserve is to get the area back to a climax cloud forest condition, which involves regenerating the primary forest vegetation, but also restoring the animal species that live in it. One of the animals that has not significantly recolonized the reserve after reforestation is the sloth.

Since 2014, there has not been any sightings of either two toed (*Choloepus hoffmanni*) or three toed *Bradypus variegatus*) sloths. Before the last sighting in 2014, not many sightings of sloth were recorded. However, before the reserve was founded in 2002 several sloths were known to be in the area (Meijboom W., 2013). The management of the reserve is considering releasing sloths back into the reserve as part of its goal to achieve a climax cloud forest condition. This statement was confirmed during an interview with Jennifer Powell, M. Sc. on 14th of august 2017. The main reasons to consider releasing sloths is that they have a role in the ecosystem as herbivores, and prey animals, and they provide habitat for other organisms such as, moths, beetles, fungi and algae (California Academy of Sciences, 2017). Other reasons are to conserve the species, provide sloths a protected wild habitat, and because sloths have a high aesthetic value for tourists that come to the reserve.

The main aim of this research is to get insight into the suitability of the habitat at Cloudbridge Nature Reserve for both Costa Rican sloth species (*Bradypus variegatus* and *Choloepus hoffmanni)*, with the main question being: is Cloudbridge Nature Reserve suitable for sloth species *Bradypus variegatus* and *Choloepus hoffmanni*?

With the sub questions listed below the main question will be answered.
- Is the climate in Cloudbridge Nature Reserve suitable for both sloth species?
- Which habitat of Cloudbridge Nature Reserve is the most suitable regarding trees?
- What are the threats in Cloudbridge Nature Reserve for both sloth species?

- What is the possible density in Cloudbridge Nature Reserve for both sloth species?
- What does a sloth soft release process look like and what are the requirements?

2. Material and methods

2.1 Research area

The research area is located near the village of San Gerardo de Rivas in the Talamanca Mountains of southern Costa Rica at the border of Chirripó National Park (See Figure 1). The area is located 9 degrees latitude from the equator and, because of that, there are no big seasonal temperature changes during the year. The average temperature during the day is around 25 degrees Celsius and during the night around 15 degrees Celsius. The average yearly precipitation is around 4370 mm (Giddy I., 2016). The reserve is located on the Pacific side of the Talamanca mountain range and ranges in elevation from 1550m to 2600m (Cloudbridge Nature Reserve, 2017).

Figure 1: Location research area. (DMS Coordinates: 09°28'19.56" N 83°34'39.68" W) *(GPS-Coordinates.net, 2017)*

Multiple streams and rivers go through the reserve. There are two main rivers, the Río Urán and the Río Chirripó Pacifico. The Río Chirripó Pacifico flows into the Río General, which flows into the Río Grande de Terraba, and eventually into the Pacific Ocean.

There are four main types of habitat present in Cloudbridge Nature Reserve, primary forest, natural regrowth older than 30 years, natural regrowth younger than 30 years, and planted forest (see Appendix I).

2.2 Data sampling

2.2.1 Suitable area regarding trees

Background knowledge was gained from the literature and interviews with The Toucan Rescue Ranch and Alturas Wildlife Sanctuary to find tree species that are getting used by both sloth species as a food source. After that, only the tree species that were also known to be present in Cloudbridge were taken into account. A list of these tree species was made, along with a recognition guide, to be able to identify the trees in the field. The number of target trees in each habitat provide a measure of the suitability of the different areas as sloth habitat.

Transects were set up in different parts of Southern Cloudbridge. Transects were plotted in the four different habitat types (primary forest, natural regrowth younger than 30 years, natural regrowth older than 30 years, and planted), so the suitability of these habitats could be compared.

In total, 20 transects were studied, with four transects in each habitat class (see Appendix II). The transects were 100 meters long and 8 meters wide. All transects started from a trail (see Appendix III). The direction of the transect was chosen in the field to avoid steep slopes and dangerous terrain for safety reasons. The total surface area of one plot was 800 m^2. For each transect, all tree species with a DBH (diameter of the tree at breast height) above 15 cm were identified and the suitability, height, DBH, canopy class, vine development, and canopy temperature of the tree was noted down. These are all considered important parameters for the preference of habitat for both sloth species (Fernando J., 2011). All suitable tree species actually found during transect are listed in Appendix IV.

Suitable trees were defined as a target tree species with a DBH of 15 cm or higher. In a previous study, the same DBH of 15 cm and higher was used because those trees are considered to be interesting for sloths (Meijboom W., 2013).

Tree height was calculated using the technique shown in Figure 2. In the field, a clinometer was used to measure the angles to the top and base of the tree and the distance to the tree was also measured with a measuring tape. Afterwards, the height of the trees in meters could be calculated with a formula (see Figure 2).

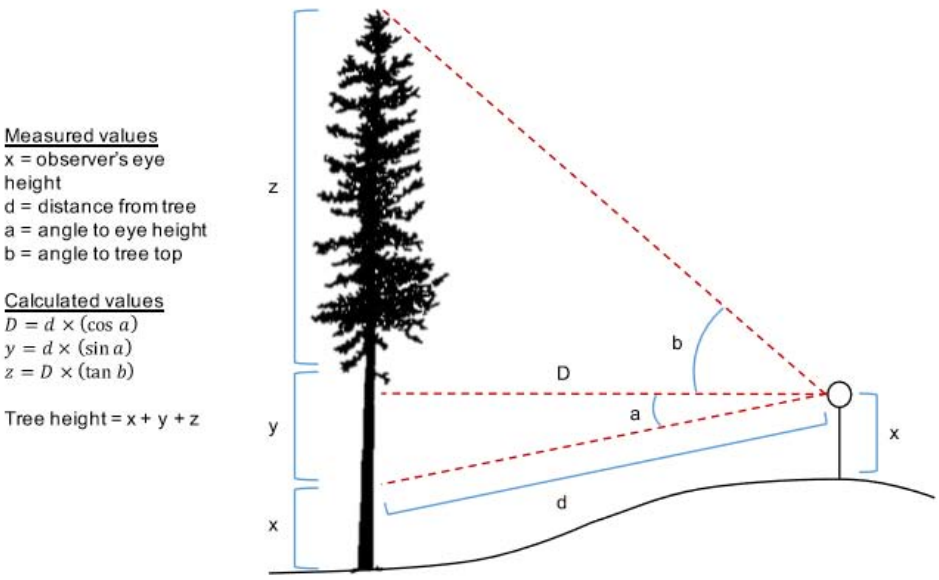

Figure 2: Tree height calculations.

Canopy class was broken down into four different classifications (dominant trees (4), codominant trees (3), intermediate trees (2), and supressed trees (1)). Vine development was classified 1 to 4, with 1 meaning no vines on the tree, and 4 meaning a lot of vines on the tree. The canopy temperature was measured with an infrared surface temperature thermometer.

2.2.2 Local

Attempts were made to find a sloth in the area around Cloudbridge Nature Reserve in order to observe their habitat usage and feeding habitats by reaching out to local residents (see Appendix V). Posters were hung up outside the supermarket and were given to a local who distributed it to his contacts in the village. Unfortunately, there was no response to these posters.

2.2.3 Climate

Climate data recorded between 2003 and 2017 was compared with literature about the climate sloths are able or known to live in. A graph of the temperature data over these years was made to be able to see any trends in temperature changes. Also, the average annual temperature was calculated to be able to compare this with other locations where sloths are known to be present. In addition, annual rainfall data from Cloudbridge was compared with other habitats where sloths are known to live to see if they can live in similar conditions.

2.2.4 Threats and limitations

The general threats to and limitations of sloths were compared with the threats and limitations present in Cloudbridge. Part of the threat assessment was to look at the presence of possible predators. Data from a camera trapping study at Cloudbridge was used to find which predators are active in the reserve and the amount of sightings in 2016 and 2017. For the cat species data, the events were also divided by the amount of days the cameras were running, to get a more realistic representation.

2.2.5 Density

An estimate was calculated for the possible density of both sloth species in the reserve by looking at the density in similar habitats and the size of the area around Cloudbridge. First the possible density in Cloudbridge was calculated and, after that, the possible density in and around the area of Cloudbridge, since sloths would be able to move around freely.

2.2.6 Requirements for a soft release process

To be able to make a description of the release process, different organisations were contacted to gather information. These were Merazonia, (Wildlife rescue, rehabilitation and monitoring centre in Mera, Ecuador), Alturas (Wildlife Sanctuary in Dominical, Costa Rica), The Sloth Institute (Non-Profit Specializing in Research and Education on Sloths, Costa Rica.), and Toucan Rescue Ranch (Wildlife Rescue Facility Costa Rica). The last two were also visited.

2.3 Data analysis

The data collected in the field was entered into an excel database.

To be able to determine the most suitable transect, the importance of each of the factors in regards to the suitability for sloth habitat, needed to be weighted. Importance scores were given to the different factors (1 = most important, 3 = least important). The two most important factors are: the amount of suitable trees and the amount of trees over 15cm DBH. One, because sloths need suitable trees to provide food, and, second, because sloths move around through the trees without going down to the ground, so they need enough trees to be able to move around (Bradford A., 2014). The second most important factors are considered not to be essential for the survival of sloths. Sloths prefer a larger amount of suitable tree species, taller trees, and a higher amount of vine development (Bradford A., 2014). Considered to be the least important is the canopy cover, but it is still a factor for sloths, because three toed sloths like to warm up in the sun in the morning, and, for both species, because with dense canopy cover they are less visible to predators from the ground (World Wildlife Fund, 2018). Based on the importance score, a weighted percentage of either 27.5, 13.0, or 6 percent was calculated and assigned to each factor, with 27.5 percent assigned to the most important factors and 6 percent to the least important (see Table 1).

Then, within each factor, the range of values found throughout the reserve were organized in ascending order (see Table 1), and for each factor, the lowest of the range was given a score of 0 and the highest 10. The highest value for each factor is what both sloth species prefer the most. Values in between were calculated as percentages of the total range.

For each transect, the score for each factor was multiplied by the weighted percentage (see Table 1) and the results for each factor were added together, to get an overall score for each transect (see Appendix VI). Using the same technique, the outcome per habitat was calculated, to find the most suitable habitat type.

Table 1: Values given per factor.

Factors	**Importance (1-3)**	**Percentage**	**Range**
Amount of suitable trees	1	27.5%	0-9
Amount of trees over 15cm DBH	1	27.5%	5-32
Amount of suitable species	2	13.0%	0-3
Tree height	2	13.0%	9.3-18
Vine development	2	13.0%	1-1.5
Canopy cover	3	6.0%	2.79-4

3. Results

3.1 Climate

Both the Hoffmann's Two Toed Sloth and the Brown-throated Three-toed Sloth cannot tolerate very cold climates and they generally prefer warm climates over cold climates. However, both species are found above 2400 meters elevation in the Braulio Carrillo National Park, Costa Rica (see Table 2). Compared to the Hoffmann's Two-toed Sloth, the Brown Throated Three-toed Sloth is less tolerant to cold temperatures, since it does not have a dense woolly undercoat, which the two-toed sloths do have. Since the two-toed sloth has thicker fur, it also has a lower thermal neutral zone (the condition in which the environment is such that the animals heat production is not increased by cold) of 18°C compared to 24°C for the three-toed sloth (Society American Meteorological, 2012). The Hoffmann's Two-toed Sloth is therefore also able to live at higher elevations. The highest two-toed sloth individual was found at 3328 meters above sea level at the Turrialba Volcano in Costa Rica. Hoffmann's Two-toed Sloths who live at lower elevations are known to have thinner fur than individuals that live at higher altitudes (Gilmore D.P., 2000).

Brown throated sloths in Costa Rica are found in Monteverde, which has an annual average temperature of 18.8 degrees Celsius. This is higher than the average annual temperature in Cloudbridge Nature Reserve; 17.7 degrees Celsius (see Appendix VII). However the annual average temperature of Monteverde cloud forest was collected at an elevation of 1460m above sea level. Brown-throated sloths are also known to live in cloud forest and above 2400 meters above sea level in the Braulio Carrillo National Park, which most likely has a lower annual average temperature than Cloudbridge Nature Reserve (Gilmore D.P., 2000). Hoffmann's Two-toed Sloths are also known to live in a cloud forest in Colombia were the annual average temperature is 13.0 degrees Celsius, which is lower than the annual average temperature in Cloudbridge Nature Reserve.

Both species are known to live in similar habitats regarding the annual rainfall. In Cloudbridge Nature Reserve, the annual rainfall is 4370 mm and in the Braulio Carrillo National Park it is between 4000 and 8000 mm per year (Costa Rica Guide, 2018).

With comparing the climate of habitats where the Hoffmann's Two-toed Sloth is known to be present and the climate of Cloudbridge Nature Reserve, the result is that this species would be able to survive in the climate. For the three-toed sloth, the average annual temperature of Cloudbridge Nature Reserve appears to be too low, but looking at the elevation difference of the recorded data and looking at the upper elevation range of 2400 meters, the climate is also considered suitable.

Table 2: Climate criteria sloth species compared with Cloudbridge (Green = Criteria is suitable; Red = Criteria is not suitable).

	Hoffmann's Two-toed Sloth	**Brown-throated Three-toed Sloth**	**Cloudbridge Nature Reserve**
Max. Elevation in meters	>2400 (3328)	>2400	1550 – 2600
Min. Annual average temp.	13°C	18.8°C	17.7°C
Annual rainfall	4000 – 8000mm	4000-8000mm	4370mm

3.2 Suitability regarding trees

The calculated index per habitat shows that “Natural regrowth over 30 years” (25.2) is the most suitable habitat type for both sloth species within Cloudbridge Nature Reserve. The second best is “Primary forest” (20.4). After that the “Planted” (14.1) habitat is the most suitable and the least suitable habitat is “Natural regrowth under 30 years” (12.2) (see Figure 3). The habitat “Natural regrowth over 30 years” has 4 out of 5 transects in the 6 highest scored transects.

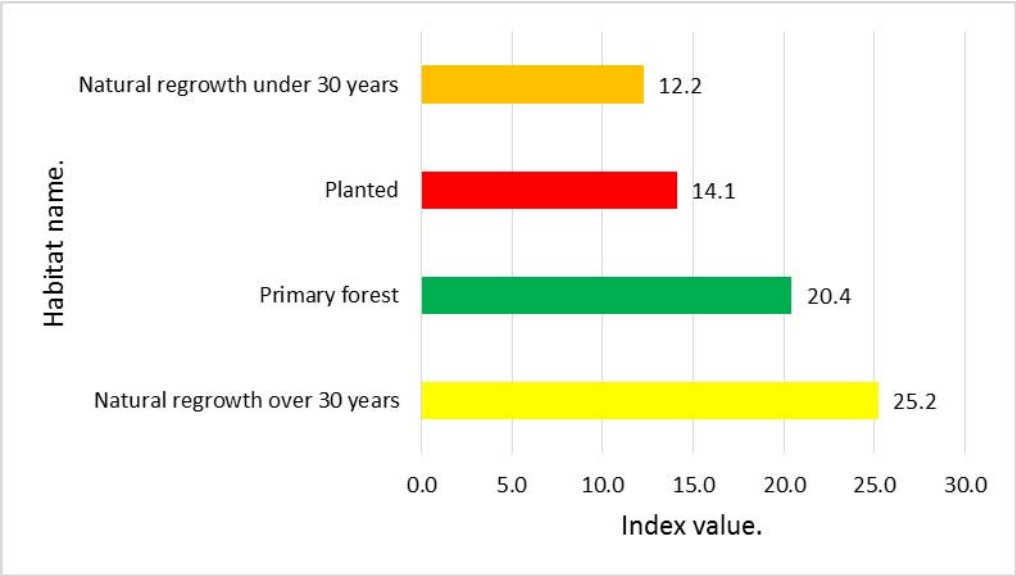

Figure 3: Index value per habitat type for both sloth species in Cloudbridge Nature Reserve.

The index value per transect shows that the most suitable transect is “SF2” (7.7), which is located in the “Natural regrowth over 30 years” habitat type (see Figure 3). The two most suitable transects stand out well above to the other 18 transects. The most suitable transect has the highest score based on the amount of suitable trees and tree height, which are both considered the two most important factors. Besides this, “SF2” has a high amount of trees above 15cm in diameter at breast height.

The second most suitable transect, “PF2” (6.9), has the highest score based on the amount of suitable species and has the second highest score based on the amount of suitable trees. Besides this, “PF2” also had one of the highest scores on the amount of trees above 15cm in diameter (see Figure 4).

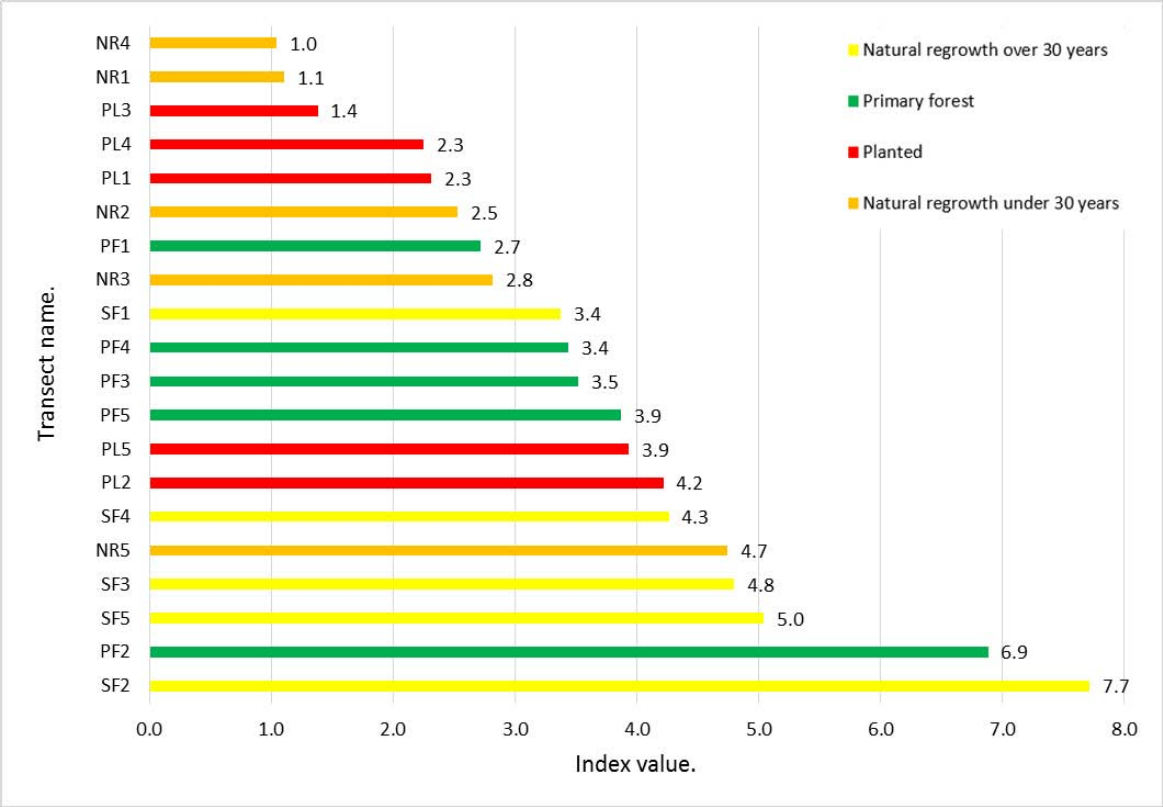

Figure 4: Index value per transect for both sloth species in Cloudbridge Nature Reserve.

3.3 Threats

3.3.1 Human threats

At the global level there are no major threats for either the Hoffmann's Two-toed Sloth or the Brown Throated Three-toed Sloth. However, on a smaller scale there are threats for sloths. The biggest and most common threats are from human impact. These are: habitat fragmentation, hunting, the pet trade, dogs, and powerlines (Trull S., 2014).

Habitat fragmentation is not occurring anymore in and around Cloudbridge Nature Reserve. There is no hunting taking place and there is no impact from the pet trade. Besides this there are no dogs allowed into the reserve and there are no powerlines above ground. The major human threats are therefore not present in Cloudbridge Nature Reserve.

3.3.2 Non-human threats

The biggest non-human threat is predation. Part of the sloths' role in an ecosystem is as a prey animal. There are multiple predators that are known to predate on sloths. Their main predators are: Harpy Eagles (*Harpia harpyja*), Ocelots (*Leopardus pardalis*), Pumas (*Puma concolor*), Jaguars (*Panthera onca*), Margays (*Leopardus wiedii*), and Anacondas (*Eunectes murinus*) (Hayssen V., 2011) (Ricardo S. Moreno, 2006). Besides these predators, predation by Spectacled Owls (*Pulsatrix perspicillata*) has also been found (Bryson V.J., 2009).

Of these natural predators, the Ocelot, Puma, Jaguar, Margay, and Spectacled Owl have been recorded in Cloudbridge Nature Reserve. During an interview conducted on the 16th of January, 2018, Jennifer

Powell, M.Sc. stated that the Spectacled Owl only has been recorded by one researcher and it has not been recorded since, making the original identification suspect.

The predator that has been recorded the most on camera traps in the last two years is the Puma, with 13 events (see Figure 5 and Appendix VIII). Second most recorded are the Ocelot and Margay, with 6 events both. There were 3 recordings of Jaguar, as well as 7 recordings of smaller cats that were not possible to identify to species.

With the events per species divided by the days the cameras were running, the Jaguar has the highest ratio (1.41). Mainly because there was 1 recording at a location where the camera was only operational for 8 days. Second highest is Puma (0.86), followed by Ocelot (0.54), and Margay (0.32).

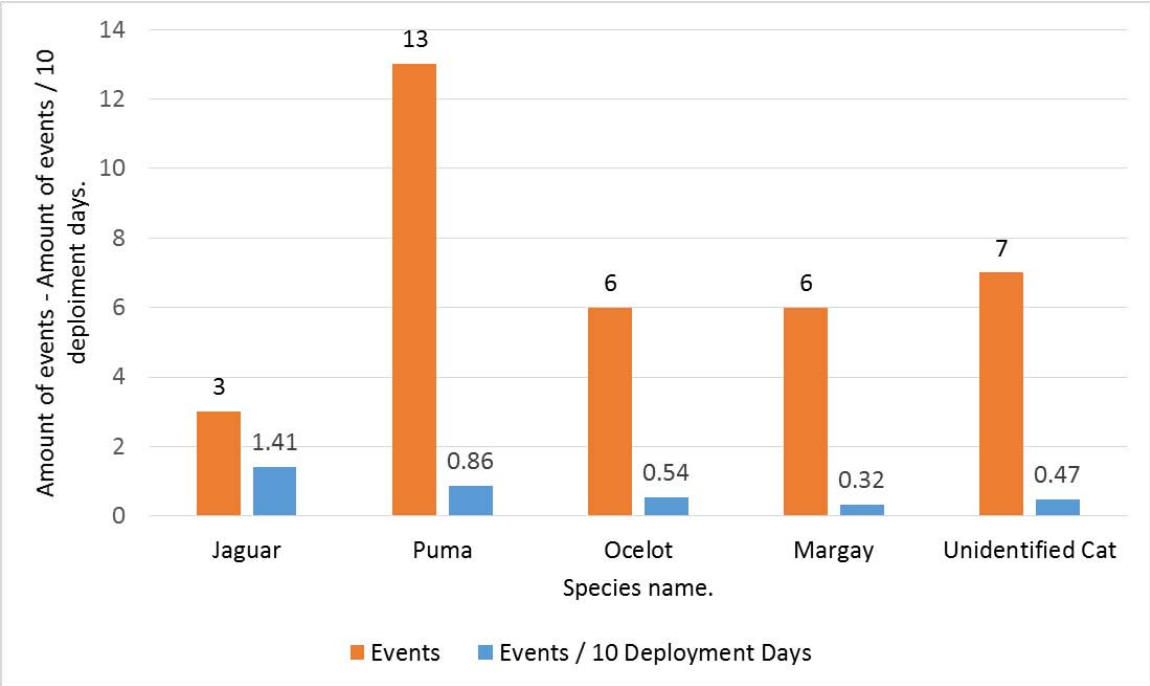

Figure 5: Camera trap events of sloth predators (cat species) in Cloudbridge Nature Reserve (2016-2017).

The predators in Cloudbridge could be a problem, so a solution has to be thought of to be able to reduce this possible risk.

3.4 Sloth Density

The possible amount of sloths, for both species, is calculated for three areas: the most suitable habitat type in Cloudbridge Nature Reserve "Natural regrowth over 30 years", the total size of Cloudbridge and the forested areas around Cloudbridge (see Appendix VII). For the Hoffmann's Two-toed Sloth a range of 0.079 – 1.5 animals per hectare was found (Superina M., 2010). Generally Brown Throated Three-toed Sloths are found in higher densities than Hoffmann's Two-toed Sloth. The density range found for Hoffmann's Two-toed Sloth is 0.6 – 12.5 animals per hectare (see Table 3) (Superina M., 2010).

Table 3: Calculated amount of sloths possible within Cloudbridge Nature Reserve.

	NR over 30 years	Cloudbridge	Cloudbridge and further
Size in hectares	65,09	283	10,474*
Amount of Hoffmann's Two-toed Sloths possible. (*Density range: 0.079 – 1.5 animals per hectare*)	5 – 97	22 – 424	827 – 15,711
Amount of Brown Throated Three-toed Sloths possible. (*Density range: 0.6 – 12.5 animals per hectare*)	39 – 813	169 – 3537	6284 – 13,0925

* (see Appendix IX)

3.5 Soft release site and requirements

3.5.1 Release process

During a visit to The Sloth Institute from the 12th of January 2018 until the 14th of January 2018, interviews were conducted with Sam Trull and Tom Lawrence about information on their release process. The Sloth Institute is a non-profit organisation that focusses on research and education on sloths in Costa Rica. They have released four hand-raised Hoffmann's Two-toed Sloths in 2017 from their release site near Manuel Antonio, Costa Rica. The sloths that were released are being tracked and behavioural data is written down by researchers. Besides this, they also track 2 wild Hoffmann's Two-toed Sloths and 6 Brown Throated Three-toed Sloths.

They observe the wild three-toed sloths during the day from 6:00-18:00 and the two-toed sloths, both wild and released, at night from 18:00 – 6:00. With the help of around 10 volunteer researchers, they are researching if there is a difference in behaviour between hand-raised released sloths and wild sloths.

It is possible to soft-release sloths when they reach a certain weight, when the weight of the collar is 3 percent of the total body weight of the sloth. When this is the case, the weight of the collar does not affect the sloth. For the three-toed sloth, this is 3 kilos and for the two-toed sloths, 4 kilos, since they use a different kind of collar.

During the rehabilitation of the sloth they are grouped according to their size, skills and health. They practise climbing and foraging in small trees, but they still need to be taken care of around the clock. When they are starting to show natural behaviour and are big enough, they are placed in a large pre-release cage (H. Jordan, 2018). The size of this cage is 6 x 6 x 6 meters and has a separation in the middle, so the cage can be split into two parts. It is possible to house two adults or four young sloths in either side of the cage. Preferably the sloths from different species are not put together in one section, since they have different needs.

Ropes hang in the cage to make it easier for them to move around. It will be best to have a natural floor inside the cage, so it is more natural for them to go to the bathroom. Besides this there are pulley systems for food and branches. Mosquito netting on the cage keeps out unwanted animals such as snakes. Tarps cover half of the cage so a part is protected from the rain. Also, around the cage green rope is put up with red pieces of tape and bells hanging from it about half a meter from the ground, to scare away predators.

The sloths are raised in this cage until they reach the required weight. Then the doors are opened and the sloth can decide for itself if it wants to leave the cage or to stay inside the cage. Four feeders

are put a small distance from each corner of the cage, to encourage them to go out of the cage. Also ropes are put up from the cage to nearby trees, to make it easier for the sloths to move around and to reach the feeders. The feeders are filled every evening, around the time the two-toed sloths get active, with cooked carrot, green beans, chayote, and fresh lettuce. At the Sloth Institute, the sloths are still fed the same amount of food after a few months.

3.5.2 Requirements

First of all, a release cage is needed to be able to soft-release sloths. Depending on the process, how long the sloths need to stay in the cage and how many sloths are planned to be in the cage, the size may be different than the 6 x 6 x 6 meters cage at The Sloth Institute. It is better to find a flat piece of ground to build the cage on, which makes building and, later on, working around the cage easier. From the cage, feeders on pulley systems are required to be able to feed sloths high off the ground. To those feeders, and possibly suitable food trees for sloths, ropes need to be hung up to make the first steps outside the cage easier.

To be able to track the released sloths and record data, collars and a VHF tracking device is needed. Also for this, there need to be volunteers to track the sloths and keep an eye on them.

The Sloth Institute also had a small laboratory to bring sloths to for health check-ups or when the collar needs to be changed. It is possible that such a place would also be required at Cloudbridge, but this is not certain.

4. Discussion

In a previous study conducted in Cloudbridge Nature Reserve in 2013 by Wouter Meijboom, it was concluded that primary forest is the most suitable habitat type within the reserve. Which is contradictory to the findings in this study that found that natural regrowth over 30 years is the most suitable habitat. The previous study however had a very low sampling size of 5 transects compared with 20 transects in this study. Wouter Meijboom did mention that the habitat, natural regrowth over 30 years, also had potential for sloths (Meijboom W., 2013).

In this previous research done in 2013, also the possible density was calculated. It was said that if Cloudbridge Nature Reserve was completely suitable there could live 750 Brown Throated Three-toed Sloths and 125 two toed sloths. For both species these numbers are between the minimum and maximum amount calculated in this research. Since it is not completely known in which densities they live in a cloud forest habitat it is difficult to calculate an exact number (Meijboom W., 2013).

Wouter Meijboom stated that the only threat present in Cloudbridge Nature Reserve is the presence of predators. This is similar to this study. However, he wrote that he did not think that this would be a problem when there is enough food and enough hiding places (Meijboom W., 2013). This might be the case for wild sloths, but for hand raised released sloths, predators are more of a threat, since they are more vulnerable when they are close together around a cage and not as experienced in the wild. Predators are seen frequently on camera traps in the reserve and a solution to keep predators at a distance from the release cage has to be thought of.

Sloths are in general an understudied species, compared to other mammals. There is not much information on the tree species that they use as food, especially for high-altitude sloths. Most of the information that is available is done on lower elevations. It was difficult to find a list of tree species that are known to be eaten by sloths and are also present in Cloudbridge Nature Reserve, because the trees differ with the lower habitats where most of the studies are carried out.

5. Conclusion

The climate in Cloudbridge Nature Reserve is considered suitable for the Hoffman's Two-toed Sloth and the Brown Throated Three-toed Sloth. The most suitable habitat type is natural regrowth over 30 years old and the most suitable transect is SF2, this transect has the most amount of suitable trees and the tallest trees. The second most suitable transect, which together with the first one stands out above the others, has the most suitable species, and the second highest score on the amount of suitable trees. The only threat is the presence of predators. The possible density that sloths can live in the most suitable habitat, which is a size of 65.09 hectares, is for the Hoffmann's Two-toed Sloth, between 5 and 97 sloths, and for the Brown Throated Three-toed Sloth, between 39 and 813 sloths. Overall, Cloudbridge Nature Reserve is found suitable for both sloth species.

References

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Appendix I: Habitat map Cloudbridge Nature Reserve

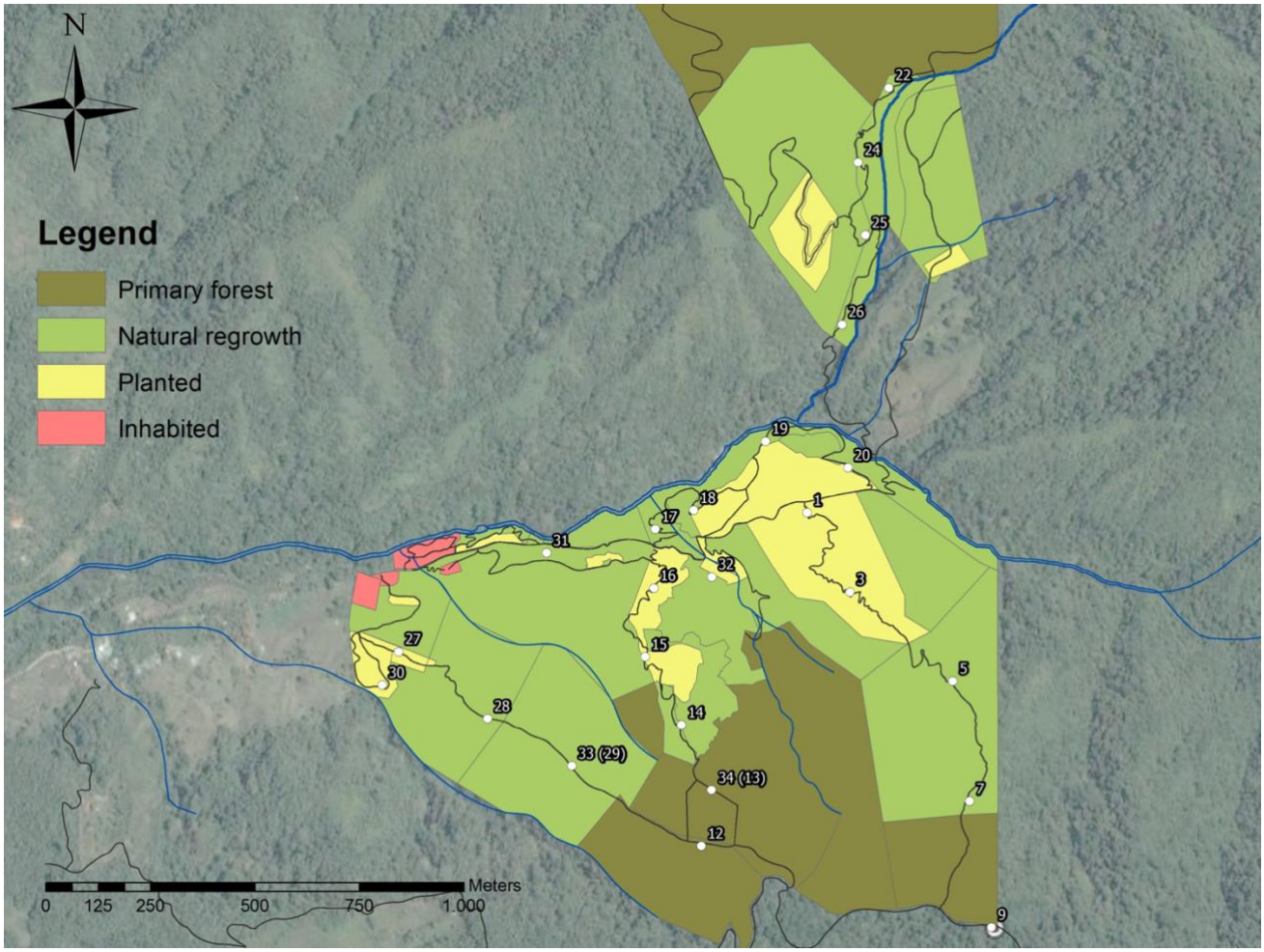

Figure 3: Habitat types in Cloudbridge Nature Reserve

Appendix II: Transect GPS locations

Table 4: Coordinates of transects.

Plot name	Habitat	Start Latitude	Longtitude	End Latitude	Longtitude
PF1 El Jilguero	Primary forest	9°28’02.45”N	83°33’55.53”W	9°27’59.42”N	83°33’54.42”W
PF2 Gavilan	Primary forest	9°27’59.14”N	83°34’17.54”W	9°28’00.94”N	83°34’21.10”W
PF3 El Jilguero	Primary forest	9°27’58.62”N	83°34’16.22”W	9°28’01.58”N	83°34’14.82”W
PF4 Montana	Primary forest	9°27’58.05”N	83°33’55.70”W	9°27’55.76”N	83°33’53.48”W
PF5 Gavilan	Primary forest	9°28’00.88”N	83°3413.67”W	9°27’58.24”N	83°34’11.64”W
SF1 Montana	Natural regrowth over 30 years	9°28’09.56”N	83°33’55.49”W	9°28’09.47”N	83°33’52.17”W
SF2 Montana	Natural regrowth over 30 years	9°28’07.34”N	83°33’55.02”W	9°28’06.16”N	83°33’51.95”W
SF3 Montana	Natural regrowth over 30 years	9°28’01.07”N	83°34’22.10”W	9°28’04.01”N	83°34’23.38”W
SF4 El Jilguero	Natural regrowth over 30 years	9°28’02.81”N	83°34’24.89”W	9°28’02.50”N	83°34’21.58”W
SF5 Jilguero	Natural regrowth over 30 years	9°28’07.31”N	83°34’30.66”W	9°28’06.36”N	83°34’27.51”W
NR1 Main trail	Natural regrowth under 30 years	9°28’23.29”N	83°34’13.97”W	9°28’20.92”N	83°34’11.73”W
NR2 El Jilguero	Natural regrowth under 30 years	9°28’11.03”N	83°34’36.09”W	9°28’09.53”N	83°34’32.81”W
NR3 Rio	Natural regrowth under 30 years	9°28’30.40”N	83°34’05.82”W	9°28’30.00”N	83°34’09.17”W
NR4 Main trail	Natural regrowth under 30 years	9°28’23.44”N	83°34’13.21”W	9°28’20.92”N	83°34’11.09”W
NR5 Heliconia	Natural regrowth under 30 years	9°28’20.32”N	83°34’27.81”W	9°28’17.75”N	83°34’27.22”W
PL1 Rio	Planted	9°28’26.58”N	83°34’03.55”W	9°28’26.61”N	83°34’06.88”W
PL2 Rio	Planted	9°28’26.09”N	83°34’13.14”W	9°28’26.23”N	83°34’09.88”W
PL3 Montana	Planted	9°28’20.01”N	83°34’08.11”W	9°28’17.44”N	83°34’06.49”W
PL4 Gavilan	Planted	9°28’18.09”N	83°34’20.82”W	9°28’15.83”N	83°34’22.06”W
PL5 Rio	Planted	9°28’25.95”N	83°34’13.14”W	9°28’24.21”N	83°34’11.73”W

Appendix III: Map with transect locations

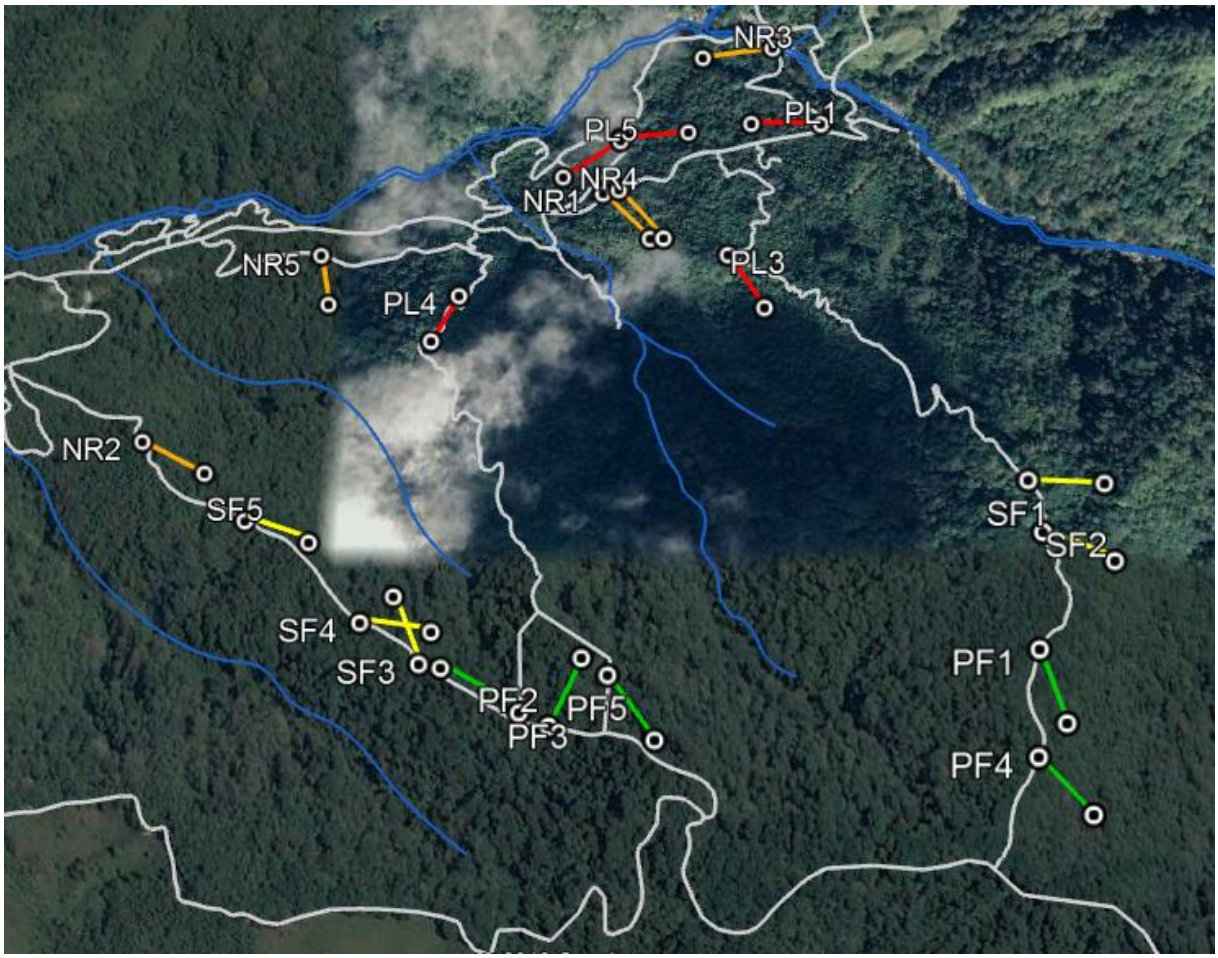

Figure 2: Cloudbridge map with plot locations. (Planted = red; Natural regrowth under 30 years = orange; Natural regrowth over 30 years = yellow; Primary forest = green; Trails = grey; Water=blue)

Appendix IV: List of Suitable tree species in Cloudbridge Nature Reserve

Table 5: Suitable tree species found in Cloudbridge Nature Reserve.

Suitable tree species found in Cloudbridge Nature Reserve
Trema micrantha
Myrsine coriacea
Inga oerstediana
Cecropia polyphlebia
Licania platypus
Inga sp.
Ficus sp.
Clusia sp.

Appendix V: Poster made for local outreach

CLOUDBRIDGE
NATURE RESERVE

Cloudbridge necesita tu ayuda!

Para una investigación tratando el comportamiento alimentario de los perezosos cerca de San Gerardo de Rivas.

Gane 50,000 Colones si nos puede mostrar un perezoso salvaje!

Ponte en contacto con Cloudbridge si ves un perezoso
Jenn.powell@cloudbridge.org

Three toed sloth (*Bradypus variegatus*)

Two toed sloth (*Choloepus hoffmanni*)

Figure 5: Poster for locals.

Appendix VI: Calculated index values

Table 6: Index calculations per transect.

	Amount of suitable trees	Value (Amount of suitable trees)	Value * Percentage (27,5%)	Amount of suitable species	Value (Amount of suitable species)	Value * Percentage (13%)	Tree height (Median)	Value (Tree height)	Value * Percentage (13%)	Amount of trees above 15cm DBH	Value (Amount of trees above 15cm DBH)	Value * Percentage (27,5%)	Canopy (Average)	Value (Canopy)	Value * Percentage (6%)	Vines	Value (Vines)	Value * Percentage (13%)	Site Value
SF2	9	10	2,750	2	6,66	0,866	18	10	1,300	25	7,41	2,038	3,28	4,05	0,243	1	4	0,520	7,7
PF2	6	6,66	1,832	3	10	1,300	14,6	6,09	0,792	24	7,04	1,936	3,33	4,46	0,268	1	5,8	0,754	6,9
SF5	3	3,33	0,916	1	3,33	0,433	12,6	3,79	0,493	32	10	2,750	3,22	3,55	0,213	1	1,8	0,234	5,0
SF3	2	2,22	0,611	2	6,66	0,866	15,4	7,01	0,911	25	7,41	2,038	3,12	2,73	0,164	1	1,6	0,208	4,8
NR5	3	3,33	0,916	3	10	1,300	10,8	1,72	0,224	20	5,56	1,529	3,3	4,21	0,253	1	4	0,520	4,7
SF4	2	2,22	0,611	2	6,66	0,866	14,5	5,98	0,777	17	4,44	1,221	3,12	2,73	0,164	1	4,8	0,624	4,3
PL2	5	5,55	1,526	1	3,33	0,433	15,3	6,9	0,897	11	2,22	0,611	3,36	4,71	0,283	1	3,6	0,468	4,2
PL5	3	3,33	0,916	1	3,33	0,433	14,8	6,32	0,822	15	3,7	1,018	3,93	9,42	0,565	1	1,4	0,182	3,9
PF5	3	3,33	0,916	2	6,66	0,866	13,2	3,45	0,449	14	3,33	0,916	2,79	0	0,000	1	5,6	0,728	3,9
PF3	0	0	0,000	0	0	0,000	14,1	5,52	0,718	16	4,07	1,119	3,56	6,36	0,382	2	10	1,300	3,5
PF4	1	1,11	0,305	1	3,33	0,433	12,2	3,33	0,433	25	7,41	2,038	3,04	2,07	0,124	1	0,8	0,104	3,4
SF1	2	2,22	0,611	2	6,66	0,866	12,3	3,45	0,449	17	4,44	1,221	2,94	1,24	0,074	1	1,2	0,153	3,4
NR3	0	0	0,000	0	0	0,000	17,2	9,08	1,180	5	0	0,000	4	10	0,600	1	8	1,040	2,8
PF1	0	0	0,000	0	0	0,000	14,4	5,86	0,762	23	6,67	1,834	3,04	2,07	0,124	1	0	0,000	2,7
NR2	3	3,33	0,916	1	3,33	0,433	9,3	0	0,000	9	1,48	0,407	3,78	8,18	0,491	1	2,2	0,286	2,5
PL1	1	1,11	0,305	1	3,33	0,433	14,2	5,63	0,732	8	1,11	0,305	3,88	9,01	0,541	1	0	0,000	2,3
PL4	0	0	0,000	0	0	0,000	15,6	7,24	0,941	12	2,59	0,712	4	10	0,600	1	0	0,000	2,3
PL3	0	0	0,000	0	0	0,000	11,8	2,87	0,373	10	1,85	0,509	3,8	8,35	0,501	1	0	0,000	1,4
NR1	0	0	0,000	0	0	0,000	12,6	3,79	0,493	6	0,37	0,102	3,83	8,6	0,516	1	0	0,000	1,1
NR4	0	0	0,000	0	0	0,000	11,6	2,64	0,343	6	0,37	0,102	4	10	0,600	1	0	0,000	1,0

Appendix VII: Temperature data graph

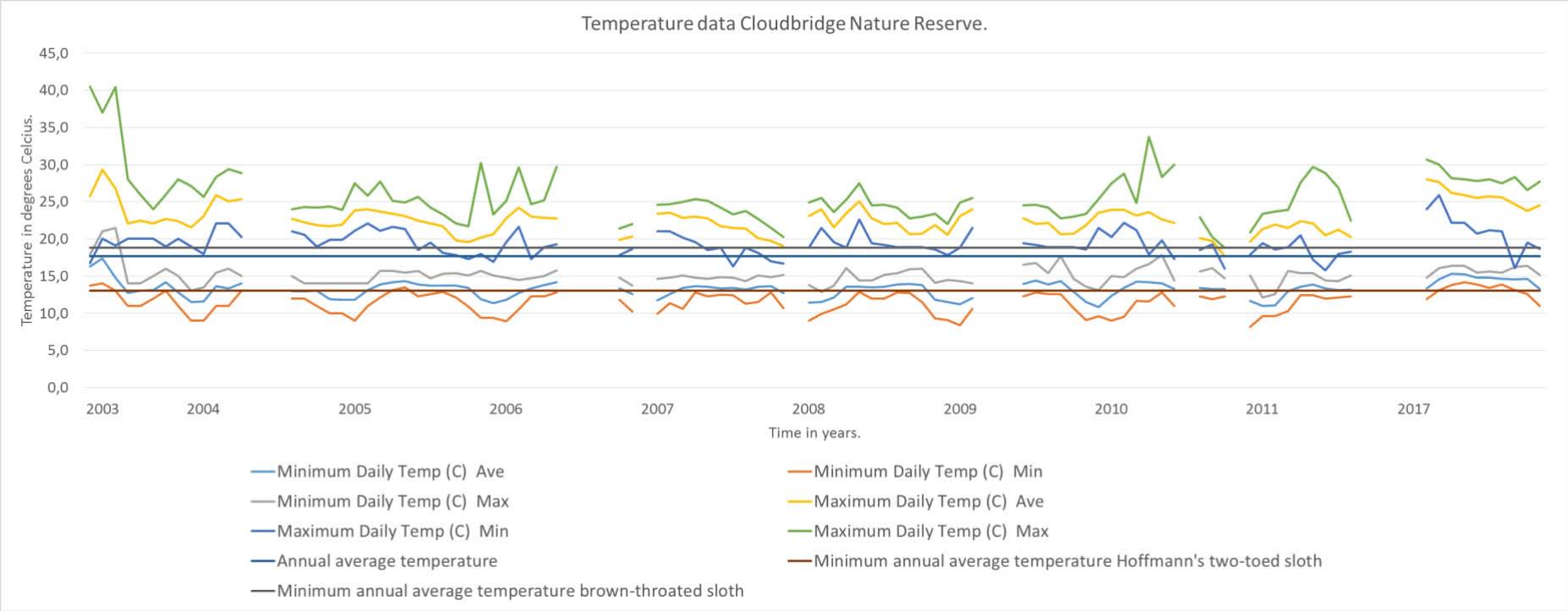

Figure 6: Temperature data Cloudbridge Nature Reserve.

Appendix VIII: Amount of cat species events on camera traps

Table 7: Cat species events on camera traps in Cloudbridge Nature Reserve.

			Events					Events / 10 Deployment Days				
Location ID	Year	Total Time Camera Operational (days)	Jaguar	Puma	Ocelot	Margay	Unidentified Cat	Jaguar	Puma	Ocelot	Margay	Unidentified Cat
E1	2016	168,28	0	4	1	4	0	0	0,24	0,06	0,24	0
E1	2017	242,75	0	2	1	2	0	0	0,08	0,04	0,08	0
G1	2016	175,63	0	0	0	0	1	0	0	0	0	0,06
G1	2017	272,88	0	2	1	0	4	0	0,07	0,04	0	0,15
G2	2016	95,44	0	2	0	0	0	0	0,21	0	0	0
G2	2017	206,71	0	1	0	0	1	0	0,05	0	0	0,05
H1	2016	100,16	0	0	0	0	0	0	0	0	0	0
H1	2017	155,85	0	0	0	0	0	0	0	0	0	0
K1	2016	29,47	0	0	0	0	0	0	0	0	0	0
K1	2017	8,17	1	0	0	0	0	1,22	0	0	0	0
K2	2016	50,60	0	0	0	0	0	0	0	0	0	0
K2	2017	78,42	1	0	0	0	0	0,13	0	0	0	0
K3	2016	46,21	0	0	0	0	1	0	0	0	0	0,22
K3	2017	43,09	0	0	1	0	0	0	0	0,23	0	0
M2	2016	0,00	0	0	0	0	0	NA	NA	NA	NA	NA
M2	2017	17,02	0	0	0	0	0	0	0	0	0	0
S1	2016	104,64	0	1	0	0	0	0	0,10	0	0	0
S1	2017	158,79	0	0	1	0	0	0	0	0,06	0	0
V1	2016	159,12	1	0	0	0	0	0,06	0	0	0	0
V1	2017	91,23	0	1	1	0	0	0	0,11	0,11	0	0

Appendix IX: Map of area around Cloudbridge Nature Reserve

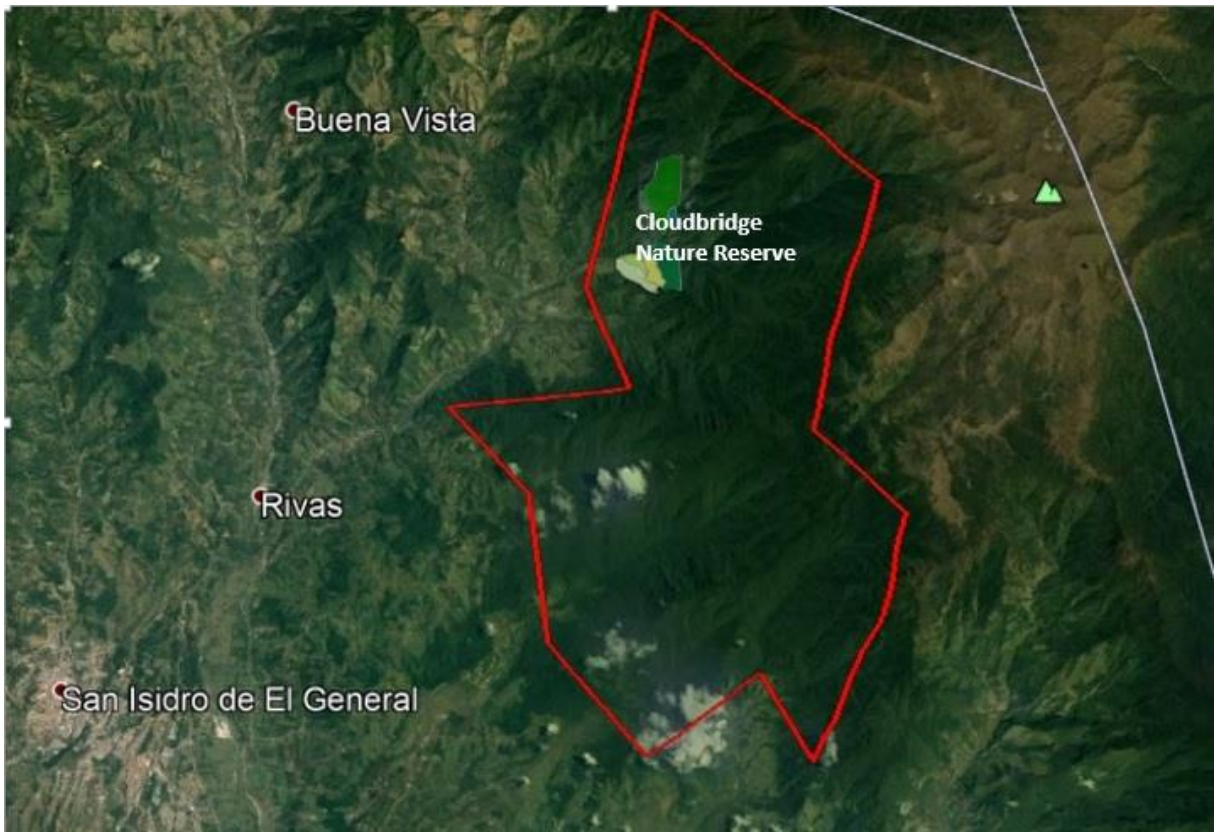

Figure 10: Density calculation map area around Cloudbridge Nature Reserve.